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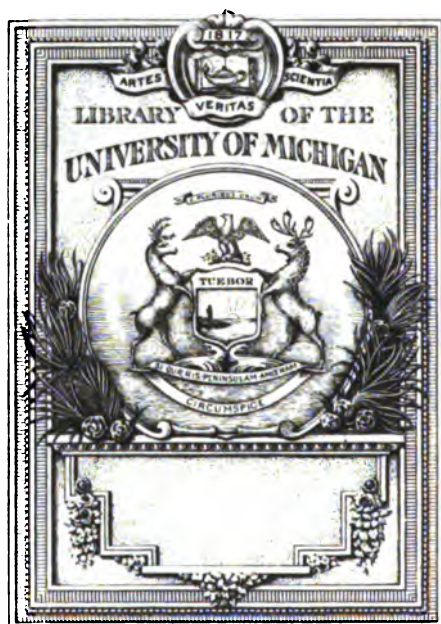
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UNIVERSITY OF VERMONT
AND STATE AGRICULTURAL COLLEGE

VERMONT AGRICULTURAL
EXPERIMENT STATION

BURLINGTON, VT.

BULLETIN No. 155

SEPTEMBER, 1910

Principles and Practice of Ice Cream Making

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**BULLETIN 155: PRINCIPLES AND PRACTICE OF ICE
CREAM MAKING**

By R. M. WASHBURN

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I. SUMMARY

The output of the ice cream industry of the United States is worth considerably more than \$100,000,000 annually. The trade in this commodity has increased enormously of late years. The profits to be derived from the use of cream in the making of ice cream as compared with the making of butter are fully double. Many Vermont creameries are so located that they could enter upon this business to great advantage, and the entire product of several Vermont creameries is being thus used to-day. Pages 9, 85-87.

This industry has thus far been but slightly studied. The present bulletin is believed to record the first serious attempt to that end thus far published. The statements it contains are based upon the records of over 500 experimental batches of ice cream and upon personal experience for a considerable length of time in several large commercial plants, in which the ideas herein broached were applied to commercial operations. As a proof of their applicability thereunto, it is perhaps enough to say that their adoption in one large factory resulted in an increased output of at least equal quality worth several hundreds of dollars monthly. Pages 9-23.

Classification of Ice Creams. There are two general classes of ice cream recognized; the plain (raw), and the French (cooked custard). Page 23.

Essential Characteristics. The flavor is influenced by the fat content of the cream; by its freedom from contamination of all sorts; by a low cream acidity; by the addition of minute quantities of common salt; and by the ripening or aging of the ice cream. A good body is the result of the presence of plenty of fat, but not too much; of the aging and thorough cooling of the cream; and, sometimes, of the use of fillers. A fine texture is promoted by the richness of the cream; by the proper conduct of the freezing process; by the aging of the cream; and, if the goods are not to be used promptly, by the use of a gelatinoid binder. Swell (or over-run) is caused by the incorporation of air into the cream, and is affected by the viscosity of the cream; by the rate of freezing; and particularly by the length of time elapsing while the cream is dropping from 34° to 29° F.; and by the speed of the agitating mechanism. The richness or leanness of the cream within working limits has but little effect thereon; neither does the use of gelatin, gum tragacanth or other binders. The time element in the conduct of the process depends upon the initial temperature of the cream; upon the rate of flow of and the temperature of the brine or upon the proportions of salt and ice used; upon the fineness or coarseness of the fragments of ice and the particles of salt; and upon the amount of sugar used in the cream. Pages 23-33, 46.

The Cream. Its flavor, fat content, warmth or coldness, acidity, the method of handling (separation, pasteurization, homogenization, etc.); all these have effect upon the final product. A clean cream is of course essential. Neither a very rich nor a too thin cream should be used, about 22% fat seeming ideal. A day's keeping improves cream, and if it is kept cold so much the better, since the fat globules harden and a better body is obtained. Acidity is to be decried, although unless excessive it is not fatal to success. A pasteur-

ized cream, if allowed to age, may be used to advantage. The homogenization of cream greatly increases its viscosity and tends to better the body, texture and general creaminess of the final product. There is no essential difference between centrifugal and gravity creams as used in ice cream making. Condensed milk may be used to advantage to better the body and smoothness of the goods. Pages 33-40.

Fillers and Binders. A filler is used to give body; a binder to prevent coarse crystallization when held for one day or longer. Starch, flour, eggs and rennet are used as fillers with greater or less satisfaction, generally less. Gelatin, gum tragacanth and ice cream powders are used as binders often with good satisfaction; but their use, though legal in Vermont, is forbidden in several states. There appear to be arguments on both sides of the question as to the advisability of the use of binders in commercial cream. The adverse arguments are that inferiority and age are thus concealed, the swell unduly augmented, the use of low grade materials encouraged, insanitary holding conditions favored and adequate food control rendered difficult. Those advanced in favor of their use are that they prevent granulation and consequent deterioration, discourage the return and re-usage of unsold goods, and assist trade regulation. Pages 42-54.

Types of Freezers. Several types and variants therefrom are in use, the principal ones being vertical-batch-ice, vertical-batch-brine, horizontal-batch-brine, and horizontal-continuous-brine. Pages 54-57.

The Freezing Process. The successful conduct of the freezing process depends largely upon the salt and the ice, their fineness or coarseness, and the proportions used, or the temperature and rate of flow of the brine; upon the rate of speed of the dasher; upon the stopping of the freezer at the proper time, or the drawing away at the proper temperature; and upon careful attention to matters having to do with the transference, the holding, and the shipping of the product.

Certain abnormalities occasionally occur, as for instance churning in the freezer, which may be avoided by cooling the cream in advance and the use of a slow initial speed.

A softened cream may be rehardened, but the outcome is generally unsatisfactory; or it may be refrozen, but the process has its dangers. It is often better to make such products into butter. The fat globules of a partly melted goods rise in the holding can, rendering the top portions richer than the bottom. Fat and fillers have no effect upon the freezing point, but sugar depresses it. Pages 57-68.

Formulas. Several formulas for staple and desirable kinds of ice cream are printed on pages 68-73.

Miscellaneous considerations. The reasons for, the necessity of and the directions for modifying and standardizing of creams used for ice cream making are described and examples of the calculations given, together with tabulated matter pertinent thereto; a scheme for the simple testing of the butter fat content of ice cream is explained; a score card for ice cream judging is suggested; the method of calculating ice cream yields is reviewed; the equipment necessary for one to enter upon commercial ice cream making on a moderate scale is indicated; the profits of the industry as compared with butter making are shown; a few unsolved problems are briefed; references are made to literature which will prove helpful to operators; the scant bibliography is listed; and the bulletin is closed with an index. Pages 73-92.

II. INTRODUCTION

Time was, and that not long ago, when almost the entire dairy output of Vermont was made into butter and cheese. The cheese-making industry for some time has been rapidly diminishing, and butter-making is also relatively on the decline. This is due mainly to the increased sale of milk and of cream to the large cities of southern New England and New York. In view of the fact that no inconsiderable proportion of these products is consumed in the form of ice cream and that today the entire product of several Vermont creameries is being thus used, a study of the ice cream industry has direct bearing upon the modern usage of Vermont's principal agricultural product.

Few people realize the present extent of the trade in this commodity. It is probably safe to say that ten times as much ice cream is eaten today in the United States as there was a dozen years ago. The extremely occasional luxury of forty years ago, infrequently hawked about the streets of our larger cities by a few itinerant venders, is now a staple, every-day commodity, eaten as a common boarding house dessert, served at every soda-fountain, dealt out from the hokey-pokey cart in the slums at a penny a helping, or served to patients in hospitals,—the food of the millionaire and of the millhand, of all sorts and conditions of men alike in city and country. There seems reason to believe that the ice cream business in the United States today exceeds \$100,000,000 gross sales annually.

So far as the writer is aware the underlying principles of ice cream-making have never been thoroughly studied. Being an American product, the literature on this subject is doubtless almost entirely in the English language. A glance at the bibliography (page 88) shows a great dearth of published information concerning this trade. It is quite safe to say that there is no other American dairy industry representing so large an investment which has received so scant attention at the hands of investigators. This is doubtless due to the fact that the business

has only of late achieved a mature status; that it has but recently outgrown the home kitchen and the small caterer. That it now abundantly merits more thorough study than has hitherto been given it, is evident to all who know its great growth during the past ten years and appreciate the extreme meagreness of adequate information.

Ice cream making thus far has been a matter of rule of thumb, as were in their earlier days its forebears, butter-making and cheese-making. Both of these industries have profited greatly by scientific investigation as to their fundamental principles. Such study has discovered the existence of the fat globule; has shown why the churn churns and how its churnings may be made more exhaustive; has placed the control of the moisture content of butter and, to a considerable extent, of flavor and aroma within the control of the butter-maker. The modern creamery operative works by rule determined by scientific inquiry. He is the exact maker of a uniform product rather than the haphazard producer of uneven grades; and he now receives high wages. Similarly with cheese-making, scientific inquiry has shown the causes of inferior quality; has standardized rennet action; has introduced the cold curing process; and in many ways has made for uniformity and high quality of the product. It is not too much to expect that this younger dairy sister may be similarly benefited; that a study of the principles of the process may result in the determination of causes and perhaps lead to the formulation of improved methods or the modification of existing ones.

It was with some such idea in mind that the studies reported herein were begun at this Station in a small way some three years ago, and have been vigorously prosecuted during the current year. It is not felt that the present publication exhausts the possibility of investigation of this subject, to which the writer may again revert in the future; but it is felt that it does at least in part fill this hitherto open gap in dairy literature.

Acknowledgment is made of helpful suggestions offered by the station chemist; of the work done by the writer's predecessor, Prof. C. L. Beach; by Mr. A. P. Bigelow, formerly Assistant in Dairying; and by Mr. Robert S. Hall, who assisted in the experimental laboratory. Especial thanks are due to Mr. J. N. Gurdy, president of the Jersey Ice Cream Company of Lawrence, Mass., and president of the New England Ice Cream Makers' Association; and also to Mr. B. L. Kent of Burlington, Vt. These gentlemen have granted to the writer the freedom of their factories; have courteously assisted him in his study of the applicability of the experimental findings to commercial operations; and have in every way possible aided him in his study of the general problem.

This bulletin is addressed more particularly to managers of Vermont creameries and incidentally to others interested in ice cream and its making. Not infrequently managers of village creameries have sought information regarding methods of ice cream making and have expressed a desire to manufacture it in a small way for the home trade or possibly for that of nearby villages. In most cases, when such inquirers have applied to the larger makers of ice cream, they have been rebuffed and given to understand by the factory managers that the making of commercial ice cream is a difficult and mysterious process, the secrets of which had distinct monetary values and were not to be disclosed. However, on turning to the Experiment Station or to the National Department of Agriculture for suggestion, they were disabused of this idea of mystery and secrecy; but on the other hand these agencies have not been of great assistance, owing to the fact that no adequate study of the industry had ever been made. But the time has abundantly arrived when ice cream making must forsake the darkness; and this in a double sense. There must now be more light thrown upon the inadequately understood manufacturing processes; and the business must quit the cellars and other dark corners where no intruders may see, and the product made in a sanitary way

in cleanly places, that it may in all future time enjoy a standing even higher, and a usage yet wider, than at present.

It is of interest in this connection to note how the thorough study of butter-making, by promoting exactness in the process and uniformity in the product, has made that art almost a science. It has raised the requirements of the general intelligence and training of the artisan and made the butter-maker's trade a more profitable one than hitherto. The same is true of cheese-making, and may well be of ice cream making. The more the conduct of these industries is studied, the more interlocking and interdependent facts are discovered, and the more skill is required properly to manage a factory; and wages tend to rise with the increase of requirements.

ORIGIN AND DEVELOPMENT OF THE INDUSTRY¹

Frank M. Buzzell

"From motives of comfort and health, the instinct of man in all ages and climates has been to maintain his physical (if not his mental) being at a temperature as nearly normal as possible. Thus we find the natives of Iceland and other very cold climates living upon heat-producing foods, fats, tallow candles, and such delicacies, while the South Sea Islander lunches on a little fruit or cereal, or other food producing a minimum of bodily heat. This rule applies also to liquid refreshment. Hot weather creates a demand for cooling drinks, and vice versa. And we, in our day, when we sit in the coolest spot to be found on some sweltering August night and sip our favorite cold drink,

¹This article on the "Origin and Development of the Ice Cream Industry" was prepared by Mr. Frank M. Buzzell, read before the Michigan Association of Ice Cream Manufacturers and reported in the March, 1909, issue of "The Ice Trade Journal." The author of this bulletin has studied the history of the ice cream industry as extensively as his facilities would permit and believes that this article covers the ground well. It is logical, thorough enough, is as accurate a statement as is likely to be obtained, and brief enough to command attention. It has seemed to him on the whole wiser to reprint this article entire than to try to revamp or condense it or to furnish new matter.

are actuated by the same motive which has influenced our ancestors from the more recent past back to the days of Job and Solomon the Wise.

"The Bible tells us indirectly that the people of Palestine knew and appreciated the refreshing quality of snow in time of harvest. The Jews, the ancient Greeks and Romans were all accustomed to the use of snow for cooling wines and other beverages, and it is today used in this way in certain parts of Spain and Turkey.

"Only those southern localities which were favored with the proximity of snow-capped mountains could enjoy the luxury of a snow-cooled beverage or dessert. Where snow was not obtainable, liquids were, and still are, cooled in porous jars and urns exposed to cool breezes, or, in lack of a breeze, swung about to create a current of air. The principle is a familiar one. The most common method of preserving snow was to saturate it with water, having packed it closely into some receptacle, of considerable size probably, and allowing it to freeze into a kind of porous ice, from which blocks could be cut as required for use. To chill a dessert or a liquid, the dish containing it was imbedded in a larger vessel partly filled with snow and particles of ice, and the open space closely packed with it. It was then allowed to stand until it had become as cold as possible or as desired.

"Alexander the Great is said to have been very fond of iced beverages, and one of our modern varieties, the Macedoine, it is said, was named for the great Macedonian. Snow and ice were used at table in the court of Henry III of France in the hot summer months. The Italians, it is claimed, made the first improvement in the original method of cooling, which improvement was to dissolve saltpetre in water and pour a little of the solution in with the snow and ice surrounding the dish to be cooled. Later it was found that better results were attained by dropping the saltpetre directly into the snow and ice, and at the same time revolving the vessel containing the substance to be

chilled. By this means the mixture in the vessel could be brought to a fairly solid state. Wines were commonly iced in this way, then water, sweetened and flavored with various fruit juices or other flavorings, was made into a sort of water ice. Water ices and such refreshments are still the rule in the Orient, while ice cream, as we know it, is rare.

"There is no reliable record of the first water ices. Dates and places are either lacking altogether in the vague allusions made to them or are so indefinite as to be of no value. It is probable that they were brought to France from Italy by Catherine de Medici, who, preferring cookery to which she was accustomed, brought her staff of cooks with her. The date is given as about 1550. Water ices are said to have been made by Contreaux, an Italian who established a famous café in Paris. Lemonade was invented about 1630; to whom the credit belongs is not known. From water ices to mixtures containing milk or cream and eggs, was apparently a logical progression, but history is vague on the question of who first made ice cream.

"It is recorded that in Rome, a certain Quintus Maximus Gurgus, nicknamed "The Glutton," a well-known writer of those times on subjects pertaining to the table, wrote a recipe in one of his books for a dish that somewhat resembled ice cream. The name ice cream is one of modern origin, the original terms being butter ice, or cream ice, the latter being today favored in England. The earlier forms, after the ices containing milk or cream, which were really the first ice creams known, were called butter ice, probably because of their rich butter-like consistency, being made from rich cream and spaddled. Cream ice is said to have been known in Paris in 1774. Recipes for water ices and milk ices, it is claimed, were brought from Asia by Marco Polo, who visited Japan in the thirteenth century. Cream ice is mentioned in an account of a banquet given by Charles I of England. The dish was made by a French cook named De Mireo, and it is related that the king was so well pleased with the "frozen milk," as he called it, that he pensioned the cook with twenty pounds

a year on condition that he would not divulge the secret of making the dessert, nor make it for anyone but him. Another account says that the first ice cream was set before the Duc de Chartres on a hot day in August, 1774, by his chef, who had depicted the duke's coat-of-arms on the cream. Again we find in an account of an entertainment given by Louis XIV of France that 'toward the end of the feast, his chef caused to be placed before each guest, in silver gilt cup, what was apparently a freshly laid egg, colored like those of Easter, but, before the company had time to recover from their surprise at such a novelty at dessert, they discovered that the supposed eggs were a delicious sweetmeat, cold, and compact as marble.' It is also claimed that a certain Carlo Gatti first introduced cream ices into England.

"A French cook, Clermont, residing in London, gave instructions for making sweet ices in a book published in 1776. English cook books one hundred and fifty years old give recipes for cream ices in which cream and milk, sugar, eggs, arrowroot or flour and flavoring were used. Recipes have always varied according to the whim or desire of the maker. * * * * It is a question whether Germany or England first made ice cream, but it is generally conceded that the Germans led the English in making fancy moulded creams.

"We deduce from the foregoing bits of narrative that ice cream was not apparently discovered, but rather was the result of a slow process of evolution or development, which was taking place in different localities at about the same time. History states that ice cream was first sold in New York by a Mr. Hall, at 75 Chatham street, now Park Row. Ice cream is mentioned in an account of a ball given by a Mrs. Johnson December 12, 1789, and was introduced to the city of Washington by Mrs. Alexander Hamilton at a dinner at which President Washington was present. She had become familiar with the dish in New York. The first advertisement of ice cream appeared in a New York paper, the 'Post Boy,' dated June 8, 1786 and reads as follows:

'Ladies and gentlemen may be supplied with ice cream every day at the City Tavern by their humble servant, Joseph Crowe.' A negro, one Jackson, who had worked at the White House in Washington after Mrs. Hamilton introduced ice cream to President Washington learned the recipe and started a confectionery. He sold his cream readily at one dollar per quart. Others imitated him, but Jackson held his custom and prospered by making the best goods and died wealthy.

"Jacob Fussell is admitted to be the father of the wholesale ice cream business. The year 1851 found him in the milk business at Baltimore. His supply of milk came into Baltimore on the Northern Central Railway from York county, Pa. A few of his customers wanted cream, and finding that satisfactory results were not obtained by ordering cream intermittently to supply an unsteady demand, he made arrangements for a regular shipment. Here again a difficulty presented itself, for at times he found his stock of cream accumulating, which must be disposed of in the best way possible. To utilize this surplus he conceived the idea of making ice cream, the retail price of which at this time by the few confectioners who sold it was sixty cents per quart. The idea proved an inspiration, for the ice cream business soon overshadowed the milk business, which was in time disposed of. Mr. Fussell believed in the value of printer's ink and advertised his new business, and then, as now, intelligent advertising paid. Devoting his entire attention to the ice cream business, he prospered in it, and built up a large business, the success of which has continued through three generations to the present day. In 1852 and 1853 he tried out a scheme for making his ice cream at the source of supply of his raw material, rather than at the distributing point, but it did not prove successful, for while the ice cream was actually produced cheaper in the country, the fact that his own attention was divided between the two establishments, and that the stock at the selling end could not be readily controlled, counteracted the lesser manufacturing cost, and the result was that the project was abandoned

and not repeated. In 1856 the Baltimore business was left with a partner and a factory was opened in Washington, D. C. In 1862 Boston was added to the chain of plants. Here a large exporting firm, who had made considerable money shipping ice to London, India and Brazil, saw a new outlet for ice in the ice cream business. They attempted to induce Mr. Fussell to go to Brazil and start a factory there, and offered to back him with the necessary capital if he wanted it, but he was not interested. Failing to get him to send one of his men over, they arranged for one of their own men to learn the art of making ice cream, and paid a modest \$500 for the formula. How the South American venture fared is not recorded. In 1864 the New York house of Fussell was started and continued with the usual success. Here the prevailing price among confectioners was \$1.25 per quart. A Mr. [Perry] Brazelton, of [Mount Pleasant,] Iowa, a friend of Mr. Fussell, using his fortune in the panic of 1857, came to Washington and learned the ice cream business. He went back west and opened a factory in St. Louis, later going to Cincinnati and Chicago.

"American enterprise was not long in taking up the new industry, and the growth of the business commenced. However, the real development, the day of large figures in the business, had its beginning not over fifteen years ago. The brine or refrigerating system of freezing ice cream has been efficiently applied only within the past five years, and has now only fairly begun.

"The first real progress toward artificial refrigeration is said to have been made by a German in 1867, and it was then used only in breweries, and to a very limited extent. Ice making by artificial means came next. The use of refrigerating processes for making ice cream was probably begun in a way by chance, for large ice manufacturing establishments put on an ice cream department to utilize the broken or waste ice, and the possibility of applying mechanical refrigeration to the making of ice cream was no doubt thus discovered.

"Ice cream is in high favor in England, where the climate favors its use the year through. And it is used by nearly all steamship lines, especially those making long trips in warm climates. The passengers, who do not relish the indifferent quality of most foreign made goods, demand American ice cream. Every express steamer of the North German Lloyd Line leaves New York with not only a supply to care for the wants of its own passengers, but enough to furnish the Japanese, Chinese and Australian service of the company. For the far eastern service the cream is carried in refrigerated compartments to Bremerhaven and there transferred to ships sailing for ports in India, China, Japan and Australia.

"It does not seem proper to close this paper without some allusion to our friend of the lawn party, ice cream wagon, and county fair—the ice cream cone. I have heard that it was introduced in this country at the St. Louis exposition. I have found directions for preparing a freshment called "fried ice cream," sometimes known as "Alaska pie" or "Alaska fritters." The method is, briefly, to dip a cube of hard ice cream into a thin fritter batter and then to plunge it into very hot lard or olive oil. The pastry forms a good protector from the heat and hardens so quickly that the cream is not softened in the least. Another more elaborate form is said to be served in certain New York cafés to-day. The fried ice cream was introduced at the World's Fair in Chicago in 1893. It occurred to me that these freak varieties may have suggested the idea of the ice cream sandwich and ice cream cone. Whatever the origin, we will have to admit that the cone has sold many a gallon of ice cream and made many a dollar for those engaged in the business. * * * *

"I believe that the future historian of this business, who shall recount the progress of its development during the years from 1900 to 1910, cannot but remark upon that decade as being epoch making in the annals of the trade."

EXTENT OF THE INDUSTRY

"The importance of the ice cream industry in 1909 has been the subject of comment. Only in the last few years has ice cream been regarded as more than a local business. Its value as a country-wide industry has grown slowly and unobtrusively until the last year or two. In that respect it was like the candy industry. Years ago every retailer made his own candy and it was not until wholesale candy factories were put up that candy making became an industry.

"Ice cream has repeated the history of candy. It had the additional handicap, however, of being a perishable product and one hard to ship to any distance. That fact localized the making of ice cream. But gradually important business men interested themselves in ice cream manufacture, and, by applying their talents to the needs of the business, they have developed it into its present stage as one of the fastest growing industries of our commercial life.

"The brains and money that have been expended in this business have worked wonders. From being a merely retail proposition, ice cream has become a wholesale one. Where once a retailer only covered the section immediate to his store, the wholesaler now covers a city. There are now several score wholesalers who cover wide stretches of territory, shipping for 200 miles.

"The problem of economical and perfect shipment of goods has been a hard one to solve, and it by no means has been solved yet, but the ingenuity of the American has applied itself to this phase of the industry and the future holds out glowing prospects. This year or the year after may see ice cream shipped great distances in special containers that shall insure its arrival in the same condition as when packed. Already ice cream has been

¹The article on "Extent of the Industry" is quoted from *The Ice Cream Trade Journal*, issue of January, 1910, with the omission of a few paragraphs which are not relevant to the title here given.

shipped across the country in perfect condition, and a week in transit has not deteriorated its hardness.

"The last important problem will be that of long shipment, and that is being solved. Several persons think they have the answer already, but the ideas must undergo the inevitable development of all important inventions before perfection is obtained.

"The question has been asked as to the total output of ice cream in the United States last year. That is impossible to answer. It can be said with more or less certainty that the factories sold as much as 80,000,000 gallons of ice cream in the country. That means a gallon per capita. But there are countless thousands of individuals, hotels, restaurants, clubs, soda fountains, drug stores, etc.; which went on grinding out daily supplies that no one can reckon on as to amount. Twenty percent additional to the factory output might be the amount, or nearly 100,000,000 gallons, for the year.

"The value of this output also is problematical. The factories probably got on an average of 85 cents a gallon, which would mean \$68,000,000. The actual cost of the remaining 16,000,000 would be around \$8,000,000, or a total of \$76,000,000. The retail value of the 100,000,000 gallons would be about \$1.40 a gallon or a grand total of expenditure by the people of \$140,000,000 to satisfy their taste for the national dish. That shows the value and importance of the ice cream industry. To this must be added the cone business, and cakes that are served with orders for cream and the soda fountain business. Probably \$150,000,000 would no more than express the total value of the ice cream business as the consumer looks at it.

"The investment in all these lines of ice cream serving amounts to a huge sum; no one can tell how much. Perhaps \$30,000,000 would hardly cover it.

"An interesting feature of the industry to the average business concern is the supply buying. The dairy interests now count the cream demand for ice cream as being second in im-

portance to butter and better than the cheese requirement. It is sure that the requirements of the ice cream industry this year has hit the butter business hard and has lifted the price of the latter. In great sections the butter men have been put out of business by ice cream manufacturers.

"Then, too, the ice cream business has created a great demand for machinery. The modern ice cream factory demands high grade and valuable machinery. From the delicate brine freezer to the ponderous ice machine the total investment of a large ice cream factory mounts to impressive figures. Those ice machine and cold store specialty manufacturing companies, who are actively bidding for the ice cream man's trade, are doing so because they realize here is a marvellously growing field.

"Last January it was said that there were 100 ice cream factories equipped with ice and refrigerating machines. Since that time the number has more than doubled. This paper has recorded the fact that 108 ice and refrigerating machines had been installed or contracted for by ice cream men. Fully 20 must be added to this number of those not coming directly under the cognizance of the editor, or 128 in all. Thus there are in use in this field 228 refrigerating machines—pretty good for a new industry, everyone must admit.

"Next year will see even greater strides in the growth of the industry, for ice cream has the country in its grip, and probably more than 100 manufacturers will install ice and refrigerating machinery."

SCOPE OF THE PRESENT INQUIRY

The review of the general subject made preliminary to the commencement of the experimental work upon which this bulletin is largely based, showed an almost absolute lack of any accurate understanding of the principles of ice cream making. Such books and articles as are in print, and they are few in number, deal almost exclusively with recipes and small contrivances; and these are exhibited in a jumbled and unsystematic manner.

Ice cream makers themselves when discussing their own life work show no clear understanding of the principles of their business. They so often know how without knowing why; and, not knowing why, are unresourceful, and are liable to do inferior work as a result.

The statements made in this bulletin are based upon the results obtained with more than 500 carefully planned and thoroughly measured experimental batches of ice cream. The work covered a period of over two years. This experimental study was supplemented by prolonged observation and many experiments conducted in three commercial ice cream factories, each one operating a different type of machine. One of these factories averaged to make 1,000 gallons daily during the ten days during which the writer had access to the plant, another 500, and the third 100 gallons per day. The more important points determined experimentally were verified on a commercial scale in two of these factories. The writer feels that this fact serves to place quite beyond the reach of successful cavil, the applicability of the results discussed in the following pages to commercial conditions and to the making of large batches of ice cream. In other words, the ideas advanced herein are felt to be not the theoretical vaporings of one who has handled only small quantities in a gallon freezer, but to be capable of service in the making of large amounts; and, finally, several of the ideas advanced herein have been adopted in the plants in which the commercial experimental work was done, to the betterment of the product and to the increase of the profit.

The writer does not claim to have discovered *de novo* all of the facts recorded in this bulletin. He has made use of the observations of others whenever and wherever they could be obtained, and so far as practicable has acknowledged these usages, wherever they have not been matters of common knowledge.

The reader will probably be impressed with the seemingly large number of repetitions or re-statements of the same fact occurring in this bulletin. It has seemed best, however, to ar-

range the matter under certain heads and to assemble under each of these heads all of the matter which pertains pointedly thereunto. This arrangement will be found of special convenience to such as may desire to study any particular feature or point of ice cream making; but it necessitates occasional repetition of the same statement.

III. CLASSIFICATION OF ICE CREAMS¹

The term ice cream as used in this country is a rather broad one, including the product of many formulas made up in many ways. The principal divisions seem to be:

1. The plain ice cream, frequently known as the Philadelphia and, occasionally, as the New York ice cream; a plain and raw article, rarely or never containing eggs, being composed simply of cream of variable butter fat content, sugar in rather uniform quantities, and almost always containing gelatin or some other gelatinoid binder.

2. The French or Neapolitan ice cream, which contains eggs in addition to the cream and sugar, being virtually a frozen custard and as such admitting of great detailed variation.

IV. ESSENTIAL CHARACTERISTICS OF ICE CREAM FLAVOR

Ice cream is eaten primarily for the fun of it, as a luxury rather than as a food. Not that the food value of ice cream is non-existent; far from it. It is a most desirable form of food;

¹An extended classification of ice creams—covering plain, nut, fruit and bisque ice creams, parfait, moussé, aufait, puddings, "lacto" and sherbet—was discussed by Prof. M. Mortensen of the Iowa State College at the July 1910 session of the Graduate School of Agriculture, held at Ames, Iowa. This classification was printed in the agricultural and dairy press of August and September 1910 in a letter furnished by G. T. Guthrie. It has not as yet been published elsewhere, though shortly to be issued in a bulletin of the Iowa Station. As printed in the form of this letter it contains several obvious errors, which the deviser of the scheme recognizes. Hence, at his request, no further reference is made to what is evidently a much more nearly complete and thorough listing of varieties of ice creams and similar frozen dainties than that shown in the text.

but it is not likely to be chosen for its food value but on account of its pleasure-giving properties. Of these, flavor is probably the most important; hence the necessity of its close supervision.

Naturally, the amount and quality of the flavoring material or extract have a marked effect upon the character of the finished product. Choices in this respect of course are dictated by market demands and individual preferences and do not properly form any part of this discussion.

The fat content of the cream decidedly influences the flavor. A rich cream possesses a better flavor than does a lean cream, other things being equal. Above everything else the cream should be as free as possible from all contaminations, not only those ordinarily picked up at the barn and dairy, but also those indefinable dirty flavors so often found in milk products. Thorough washing with soap or washing powder, rinsing in clean water and thorough scalding or steaming are needed truly to clean metal or woodenware in which an oily material like cream has been stored. That familiar, smeary, half-greasy feel, so commonly found on dairy utensils, is proof of their uncleanness even though it is not visible to the eye. The touch betrays that which the eye does not see. Dirt is no longer merely "matter out of place," but is also a food and breeding ground for bacteria, which tend increasingly to deteriorate the quality of the product as their numbers are augmented.

Cream used in ice cream-making should contain not more than 0.25% acidity, and 0.16 to 0.18% is to be preferred. As it approaches 0.30% acidity the sour taste becomes apparent and proportionately unpleasant. However, cream which is almost sour enough to churn may be used if it is mixed with from five to ten times its volume of sweet cream, or if it is neutralized in part by the use of baking soda or of viscogen (sucrate of lime). If either is used in excess however, the cream becomes alkaline and the product has a bitter flavor.

Salt is not usually added to ice cream, purposely at least; but careful and repeated tastings by many people proved that

the unbiased consumer prefers a cream containing salt at the rate of half a teaspoonful per gallon of mixture to a cream which is not thus modified. The taste of the salt as such does not become evident until a much larger quantity is used. However, although the addition of a small quantity tends to deepen and to enrich the flavor of ice cream, it should be used with care, if regularly at all, for the reason that even a slight excess does much damage.

Ice cream is not at its best until it has stood from 12 to 24 hours to ripen. This term, "to ripen," as used in this connection is meant to cover the commingling, the blending together of all of the many flavors naturally present in or artificially added to the product. When freshly made, each separate flavor may be distinguished and singled out. Thus the rich, sweet cream flavor may be recognized, separate and apart from that of the added flavor, vanilla for instance; the unclean utensil flavor or that of the barn (manure), if dirty milk is used, can be distinguished above or through all of the others; yet after having stood for 24 hours, all of these flavors tend to blend to a considerable degree into a single flavor, the value of which depends upon the quality of the several ingredients used.

BODY

The words "body" and "texture" are used in ice cream making to mean two quite definite things. "Body" is synonymous with structure or substance. It refers to the entire mass as the unit. "Texture" on the other hand has to do with the finer makeup of the article. The structure or substance of table linen, for instance, consists of a smooth, fibrous piece of cloth. Its texture, on the other hand, indicates a lot of closely woven threads. The one has to do with the mass characteristics; the other with the arrangement of the particles.

A firm, mellow, but not hard or rubbery, body is a feature to be sought in ice cream work. *Milk solids* are the best body giving materials used. When in plentiful amounts the

general firmness of the finished article is assured; but when scanty, its body becomes weak and mushy, unless otherwise reinforced. A 25% cream affords an excellent body. An 18% cream should be deemed the minimum, for its product will begin to betray weakness. A cream testing 22% fat before the sugar is added will meet most requirements of regular work, so far as quality (body) is concerned.

Aging a cream tends to better the body of the product. Preferably a cream should not be used until it is 24 hours old as cream, or is even two days old; and if it is held cold (32° to 35° F.) during this time, so much the better. The same cream which, when used within four hours after separation, produces a weak slushy-bodied article, may, when held at 32° to 35° for 12 or more hours, produce a firm piece of goods. This change is held by some to be due to the rearrangement of the molecules of fat within the fat globule.

Pasteurized cream makes a weak, slushy and inferior article, unless it has been held cold for 12 hours or more, when it may yield a thoroughly satisfactory product. But 12 hours' aging is not its only need; it must have been kept cold for the six hours immediately preceding its use, if the best body and swell are to be secured.

Fillers. When it is difficult or impossible to control the condition of the cream which is being used, a small investment made in unsweetened evaporated milk will produce far more and better body than will an equal sum expended directly for butter fat. Gelatin, also, tends to produce a more satisfactory body. In fact a mature, tempered ice cream which contains no gelatinoid binder is weak and will yield easily to slight pressure, whereas the same cream "mix," made up with gelatin, offers more resistance at any usual temperature of holding and is found to be very slightly elastic under the touch. Wheat or rice flour, or corn starch are not infrequently used in lean creams. They are not needed in rich creams. Naturally the more such materials are used, the more like a pudding and the

less like an ice cream the goods become and the firmer will be its body.

TEXTURE

A smooth, velvety texture is desired in ice cream rather than a coarse grained mass of crystals. Milk fat is an excellent agent in the production of a smooth cream; the richer it is, other things being equal, the smoother the product, whereas, the leaner the cream, the coarser and more spiny is the finished product. However, full more important is the manner of freezing, which has much to do with success. If the mass is frozen too rapidly, it will be coarse and full of large water crystals, while if it is frozen more slowly the tendency is to improve its smoothness. This outcome is not so much due to the rate of freezing as to the amount of whipping or beating which ensues while it is freezing. If it is frozen without any agitation whatsoever, the product will be extremely coarse, even unpalatable, in fact thoroughly worthless as commercial ice cream, even though made from a rich cream, one containing say 25% fat; whereas had it been thoroughly whipped during the freezing process, enough air would have been beaten into it to have produced a light, smooth, cushiony consistency and a fine, palatable, merchantable article, even though a somewhat thin cream were used. In properly made ice cream, the water freezes in very fine crystals which are thoroughly interspersed with minute bubbles of air. When the volume of an ice cream includes 33 to 40% air, the product is more velvety in texture, more pleasing to the palate and richer to the taste, than is one containing no air. Cream fresh from the separator or pasteurizer produces a coarse grained ice cream, whereas if kept cold (32-35°) for 12 hours, it makes a smooth cream. In order that its texture may remain fine for any considerable length of time, as is necessary in commercial work, it seems to be essential that some gelatinoid binder (such as gelatin, or one of the gums) be used, for when an ice cream which contains no gelatinoid has been hardened and held

for a day or two, the water crystals grow, forming sharp spines. This unpleasant change continues to increase in extent for some days and often makes the product very unsatisfactory. Ice creams, on the other hand, which contain a gelatinoid binder remain smooth much longer and grow coarse much less rapidly.

SWELL

The overrun, or the amount (volume) of ice cream obtained in excess of the amount (volume) of total mixture put into the freezer constitutes the "swell." This increase in volume is due almost wholly to the incorporation of air into the product and, to a very slight degree indeed, to the expansion of the cream due to freezing. The amount of swell obtained is a sort of component resulting from several cooperating factors.

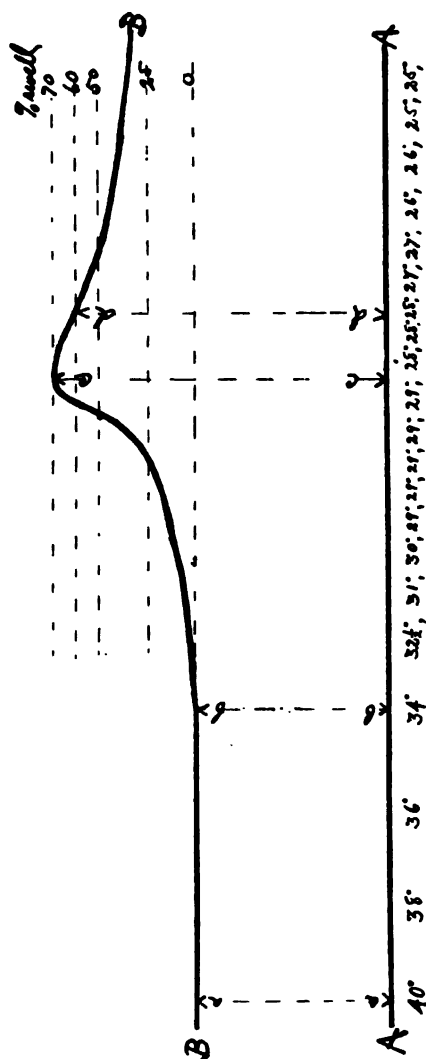
A *viscous cream* retains more of the air which is whipped into it than does a cream relatively non-viscid; hence the more viscid it is the greater the swell, other things being equal. The viscosity of a cream increases very noticeably from the hour of its separation or pasteurization for about six hours, and slowly thereafter for several days, especially if it is held cold. The cause for this increased viscosity is but poorly understood, but it seems to be due to a slight thickening not unlike the clotting of blood.

The *rate of freezing* is an important factor in this matter of increase in volume; for the reason that if the freezing be done too rapidly, too little time elapses to admit of its thorough whipping or beating, during the interval after the cream becomes cold enough to whip and before it becomes frozen. In other words, the temperature drop through the few critical degrees of cream whipping is too rapid to admit of a thorough incorporation of the air. The ordinary mixture of cream and sugar used in ice cream making is too thin and sloppy to retain any appreciable amount of the air whipped or beaten into it before it reaches about 34° F. At this temperature it begins slowly to foam up and gradually increases in volume until the tem-

perature of 29° to 28° is reached, at which point (its true freezing point, which varies from 29° to 28° , depending upon the amount of sugar in the solution, and in general practice, too, upon the accuracy of the thermometer used), the temperature ceases to drop and stands for some minutes without becoming any colder, as measured by the thermometer, nor changing its apparent condition. This stationary condition of the mix, in practice with batch machines, will continue for 4 to 15 minutes, depending upon the rate of the freezing (see page 30). It is during this time that the latent heat is being extracted from the cream and transferred into the ice, melting it. The swell, though beginning at about 34° , is by far the most rapid near the end of this apparently inactive period. In fact just before the material fully freezes, the increase is surprisingly rapid. At about this time the temperature drops to 27° and the cream becomes brittle and ceases swelling altogether. At 28° to 27° the product is ready to remove from the freezer.

Now, the rate at which cream cools depends upon several factors, chief among which are: the temperature and rate of flow of brine (brine freezer), or the amount, proportion and size of salt and ice (ice freezer); the relation of the mass of these to the mass of cream being cooled; the surface exposed for cooling action; and, finally the difference in temperature between the cream and the freezing agent.

For example, 10 pounds of ice, 1 pound of salt and 1 quart of water produce a brine of about 21° in temperature. This, acting upon 6 pounds of mix at a temperature of 70° , cooled it about 20° the first minute and 10° the second minute, yet slowed down continually so that it required a full minute to lower the temperature from 30° to 29° . So far as the swell is concerned, however, it practically all takes place during the time, be it 10 minutes or 20, in which the cream is dropping through the successive Fahrenheit temperatures from 34° to the end of the 29° period as is illustrated on the next page.



TEMPERATURE-SWELL CHART

Let the space between the lower straight line AA and the upper curved line BB represent the space occupied by the mix before, during and after freezing. Let the figures below the lower straight line represent the temperatures of the mix taken at minute intervals during the freezing process. Now, assume that the dasher is being turned at a uniform rate of speed. Then, distance aa will be the volume of the mix at the temperature 40° and bb its volume at 34°, at about which point the swell commences. It will be noted that the increase in volume continues but slowly at first, but very abruptly after the mass has been beaten at the temperature 29° for about five minutes, reaching its maximum volume, (70% swell) at about the temperature 28½° or at the point represented by the distance cc. This crest is reached at first, the point of thorough freezing. As the temperature falls to 28° for about become brittle and "beat down", to a point represented by distance dd. This crest is reached at about 28° the mass is again beaten down as indicated by the downward processes are shown.

The maximum of swell is reached at the point of thorough freezing (about $28\frac{1}{2}^{\circ}$ F.); but if the ice cream is drawn or dipped away at this critical point the warmth of the air and the tools tends to melt it somewhat, especially where it lies against the walls of the holding can. When this melted matter again freezes, coarse spines or crystals will be produced. The moment it freezes thoroughly it becomes brittle and, instead of holding more air, it slowly gives up that which it has already taken on, or, in other words, it "beats down"; hence the colder the cream is made before its removal from the freezer, assuming a uniform rate of speed for the dasher, the smaller will be the yield. In a series of trials made in a double disc, continuous freezer, run at a rate of 225 revolutions per minute, it was found that when drawn off at 29° the swell was 70%; at 28° , 60%; at 27° , 50%; at 26° , 45%; at 25° , 40%. The best temperature for withdrawal seemed to be 28° , even though at this temperature the product was thin enough to pour like heavy gravy or condensed milk.¹ Those creams with which the greatest swell was obtained required the longest time to cool through to the 17° or 16° of holding temperature. The cream does not swell at first, unless it is put into the freezer at not above 34° in temperature. Hence it is folly to run at a high rate of speed at the outset, and may even cause damage by partially churning the cream before it cools to a point below the churning temperature. When the speed is controllable, a slow initial movement followed by a rapid one when the cream reaches the whipable point, and, finally, a speed slowed down to prevent loss of swell while finishing off or carrying the cream from 29° to 28° , or from 28° to 27° , seems to be the best procedure. If this can be done carefully enough it may be hardened to 26° before removing from the freezer.

¹It may be news to the home maker of ice cream to learn that in the commercial manufacture of this product it is not usually frozen hard in the freezer, but is removed, or the dasher removed, while the young ice cream is in a semi-fluid condition and, later, hardened in an ice pack, in cans, bricks, molds, etc., at temperatures around 10° - 12° or 0° .

The amount of fat in the cream has little or nothing to do with the amount of air which may be incorporated; but it has much to do with the amount which remains incorporated. A skimmilk can be made to swell 100 percent or even more; but the product is coarse and the result only a temporary one, for it quickly loses its air and falls or sinks in the can.

In order to whip well and to remain whipped, a cream should contain from 18 to 22% fat, should be 24 hours old as cream, and should be cold. A cream containing 35 to 40% is too soggy to whip well and affords only a poor increase. The percent of swell obtained is based on the amount of "mix" and not simply on the amount of cream before sugar is added. The aim should be to obtain not less than 50%, and seldom more than 70%, of increase. A swell of 80% or more is usually obtained at the expense of body. Ice cream must not be too fluffy, or it will fall or sink upon standing, and neither consumer nor producer will be satisfied.

It may seem strange to some that an experiment station should approve of the incorporation of air into ice cream. They may reason that the station advocates the dilution of the product, the selling of "wind" as ice cream, a course quite as open to objection from the ethical, if not the legal, standpoint as is the dilution of milk with water. Such a position, however, is untenable. It is a fact that an ice cream the volume which is approximately a third air is more satisfactory to the consumer than is one containing no air. It has a more velvety feel on the tongue, and conveys a sensation of richness without causing the unpleasant effects of an excessively rich cream, in the same way that a whipped cream or a well beaten egg seems richer than does the same article in its natural state. Furthermore, the presence of air in a finely divided form causes the whole mass to be in fact partially insulated against heat conduction, so that an ice cream containing air "stands up" better both in the mouth and on the plate, than would the same cream if no air had been incorporated, and further, the whipped ice cream will chill the mouth and

stomach of the consumer far less than that made without air. Neither is the presence of air a fraud on the consumer. Where six and one-half gallons of cream "mix" is expanded into ten gallons of ice cream (54% swell) the product can, and because of competition will, be sold at a proportionately less price. The consumer will either get his ice cream for less money, or secure a larger dish for the same money. A demand that ice cream be served entirely devoid of air is no more reasonable than would be a requirement that a loaf of bread be held down to or compressed into the least possible volume. They both need to be light in order to attain the highest palatability.

V. THE CONSTITUENTS OF ICE CREAM

THE CREAM

FLAVOR

The flavor of the cream to be used in ice cream-making is an important matter. Special attention should be given to its selection and handling. Not only should it be free from the food taints occasionally introduced by the cow, and free from that "cowy" flavor which usually means merely manure flavor, but it should also be devoid of those dirty dish-water flavors not infrequently picked up at the points of ice cream manufacture. Hot water and human labor are both expensive; yet both are essential to cleanliness. It is entirely probable that some, at least, of the apparent cases of ptomain poisoning ascribed to old re-frozen ice cream were due to the action of putrefactive organisms introduced by the stale, greasy and half cold water used in washing the cans. To those who know milk and its handling, there is no flavor more disgusting. A cream which has started to sour may under stress be used, either by the use of sweet cream or by first reducing its acidity to that of normal cream, say to about 0.20% acid, using either bicarbonate of soda (baking soda, saleratus), or viscogen (sucrate of lime).¹ Care must

¹Wis. Sta. Bul. 41 (1894).

be taken, however, not to add too much, lest the cream be made alkaline and the taste bitter.

FAT CONTENT

Ice creams, or ice milks, as the case might be, were made, using varying grades of material testing 43%, 37%, 30%, 25%, 22%, 18%, 12% (cream), 8%, 4% (milk), and 0% (skimmilk). The rich 43% cream afforded a poor yield, swelling but little. It had a firm body, but was so buttery and rich in flavor that it did not approve itself to a single one of the several dozen tasters, whose verdicts in this and other trials mentioned all through this bulletin were always given in entire ignorance of the identities of the creams they were sampling. The 37% and the 30% creams met with somewhat more favor and gave better results; but they were still too rich. The cream testing 25% fat (before the sugar was added) was the choice where the swell was very moderate; but when the several lots were frozen slowly and thoroughly whipped, the consequent incorporation of air so increased the apparent richness of the cream that the 22% goods was largely preferred to that made with the 25% cream. All of these had good body. Upon reaching the lot made from 18% cream, a weakness of the body was very apparent and the spiny condition due to water crystals began to appear. The 12% goods were very weak; and everything made from milk or skimmilk was what might be termed coarse, spiny slush. An 18% fat content should be considered the minimum when making plain ice cream.

AGE

Without endeavoring to enter upon the causes which underlie the change brought about by aging cream, which is at best but poorly understood at present, it is a fact that cream and milk do in small measure clot upon standing, in somewhat the same manner as does blood; that milk is more viscid after some hours of standing than when freshly drawn, even at the same temperature (the acidity remaining the same), and considerably more

viscid after having been held cold for 24 hours. Cream likewise possesses a greater viscosity if it is held for at least 6 and preferably for 24 hours before it is used in making ice cream. This is especially the case if it is held cold in the interim.

HOLDING TEMPERATURE

Inasmuch as increased viscosity favors an increase in yield, it follows that cream intended for ice cream making should be held at a point close above freezing. This is for several reasons: At this temperature it remains sweet and usable longer than if held warmer; its viscosity is increased, thus favoring the production of a good and uniform swell in the finished article; and, because of the thorough hardening of the butter fat which the prolonged chill induces, a better body is attained. It is well known to butter-makers that the butter fat in the cream needs several hours of thorough chilling prior to churning, if good body and grain are to be attained; that butter made from cream churned immediately after cooling will be much softer in body than the same butter would have been had the cream remained cold for some six hours immediately prior to churning. The same law holds true in ice cream making. A better bodied goods may be made when the fat has been cooled for a sufficient length of time to allow thorough hardening. The most economical and efficient method of holding or cooling milk or cream with ice is to set the filled cans into a well insulated tank of water in which the ice is floating. In this way the maximum of cooling effect is obtained from the ice, and the cream or milk is cooled much more quickly than would be the case if it were set into a room, even though the air were of the same temperature as the water, as shown on the next page. Furthermore, this pre-cooling of the cream enables the maker to freeze his goods in a short space of time without cooling it too rapidly (see page 61). This feature is especially valuable where several batches must be run through the same freezer in quick succes-

sion. It also has the final advantage of practically guaranteeing that no crumbs of butter will be formed in the freezer, for all of the agitation of the cream will have taken place at a temperature far below the churning point.

KEEPING CREAM SWEET

A can of cream or milk set into cold water will cool many times more rapidly than it will if set into a dry air refrigerator, even though the air and water were kept at the same temperature. This is due to the fact that water is a much better conductor of heat than is air and that the heat carrying capacity of the mass which is able to come into contact with the can is immensely greater in the case of water; in fact the amount of heat required to be absorbed from the article being cooled in order to raise the temperature of water one degree is 445 times greater than the amount of heat required to raise the temperature of the same volume of air one degree. Or, in other words, one cubic foot of water will absorb 445 times as much heat from the can of cream as will one cubic foot of air for each degree rise in temperature. And added to these facts is another equally as important, namely, that it is next to impossible to cool the air of a refrigerator with ice much below 50°, while the common temperature is about 55°, which must be looked upon as merely the lower limit of normal souring, at which the growth of lactic acid bacteria will be slow but certain. On the other hand, the temperature of water in which a few large chunks of ice are floating will be found to range from 34° to 38°. Thus cream set away to mature, yet to keep sweet, will not only cool much faster but also to a lower point if water is employed. This system, when a well insulated tank is used, is not only the most efficient, for the reasons just given, but also the most economical of ice for the reason that practically all of the cooling power of the ice (that is, both the latent and the specific cold, if one may use the reversal term, which, though perhaps coined, serves admirably the present need), will be employed for useful pur-

poses instead of being largely wasted, as is the case when the cans of cream are merely packed close in a corner and buried with broken ice. When this is done, as is so often the case, the can is largely surrounded merely by cool air, and the ice cold water formed by the melting ice runs away to the sewer, still capable, however, of having done much good, quick work.

Housewives will do well to remember this principle when endeavoring to keep milk for children. Ordinarily clean market milk will keep sweet from two days to a week longer, or from two to three times longer if held in ice water than if held in the dry air of a kitchen ice chest or refrigerator. Another interesting point in this connection is that the entire ice box is cooled to a lower temperature when a part of the ice is put into a pail of water.

The greater cooling power of water over air, even of the same temperature, is nicely illustrated by the practise of blacksmiths who systematically plunge hot iron into water to cool instead of waiting for it to cool in air. Many other familiar examples of this principle will be recalled by the reader.

ACIDITY

The acidity of the cream has no effect upon the swell of the ice cream produced, until it reaches such a point as to cause the cream to become brittle, when a lessened yield will result. It becomes sour to the taste and smell long before the yield will be affected. Either natural, or added commercial, lactic acid seems to improve the body and texture slightly. A cream containing 0.50% or even 0.60% acid will make a good looking and good feeling ice cream, and, except for the sour taste, will be as satisfactory an article as could be desired. The sour flavor, however, will be detected if the cream possesses more than 0.26% or 0.27% of acid, and it is unpalatable to most consumers if it contains more than 0.30% to 0.32%. Cream of this quality may occasionally be used, especially if partially neutralized and then mixed with some sweet cream and frozen for im-

mediate consumption, or if it is mixed in small amount with sweet cream.

CENTRIFUGAL AND GRAVITY RAISED CREAM

The fat content being the same, there is no difference in the quantity or quality of ice cream produced from gravity raised cream and from centrifugal creams, provided the latter has been allowed to stand, as cream, for a length of time and at a temperature practically equivalent to that required for the gravity cream to rise. The process of centrifugal separation gives the cream a thorough shaking up. If it is made into ice cream immediately from the separator, the yield will be poor, the body weak and the texture coarse and spiny, whereas had the same cream been kept cold for 12 or more hours, it would have produced practically twice the swell with a firm body and smooth texture.

PASTEURIZED CREAM

The pasteurization of sweet cream improves its keeping qualities and general market value; but it decreases its apparent value and causes it to seem to be of less value than it really is because of the lowered viscosity resulting from the employment of the process. This peculiar and well recognized effect is apparently due to the impairment of the clustering tendency of the fat globules. The process in no wise affects the food value of the cream and it enhances its service for many purposes; but it decidedly affects its appearance. Viscosity (sucrate of lime) has been used to re-establish the viscosity of pasteurized cream¹. While it is effective to this end, it is not a sufficiently active agent to warrant its regular use in ice cream making, for the reason that the lapse of time and the employment of a low temperature bring about in pasteurized cream the essential return of its original viscosity. In the experimental work now under survey, creams of different fat contents were

¹Its use is illegal in several states and is to be decried under all circumstances unless its presence is declared to the consumer.

thoroughly mixed and divided. One-half of each lot was pasteurized and the other half worked up in the raw condition. It was found in all cases that where the cream was allowed to stand cold for 24 hours after pasteurization, it yielded as large a volume of as good bodied an ice cream as was that produced by the raw check lot, kept under similar temperature conditions for the same length of time. Hence pasteurized cream may be freely and successfully used in ice cream making, if it is allowed time to re-establish its viscosity.

HOMOGENIZED CREAM

A homogenized cream is one which has been made homogeneous or identical throughout its entire mass by having been passed through a special apparatus which, under pressure of from 3,000 to 5,000 pounds per square inch, so breaks up the fat globules in the milk or cream as almost absolutely to prevent all cream from rising. It also makes it extremely difficult or impossible to do thorough skimming even by centrifugal force; neither may the cream be churned. But its viscosity is greatly increased, a change in character which obviously lends itself particularly well to ice cream making.

This homogenizing of cream is a new proposition in America; but it seems destined to have a future. Not the least interesting of the many things this new mechanism is capable of doing, is the reuniting of an unsalted butter and skim milk to form a milk or a cream of any desired grade. This possibility offers enticing opportunities to those who are finding it increasingly difficult to provide the trade with sweet cream during certain portions of the year.

This process enables the ice cream maker to use a cream carrying from 16 to 17 percent fat, and to secure in his final product a body and texture fully equal to that produced by the ordinary unhomogenized 22% and 25% creams. If homogenized cream is used alone, the results are often disappointing. If, however, $\frac{4}{5}$ to $\frac{9}{10}$ of the total quantity of cream used is

homogenized, while the remaining portion consists of normal rich, raw cream, the results are almost sure to be satisfactory. The addition of even a small quantity of a cold 24-hour old milk to homogenized cream materially improves its ice cream making qualities. Cream homogenized at about 175° possesses a peculiar clinging flavor, resembling that of starch. This peculiar effect impairs the eating quality of the product, unless it is allowed time in which to overcome it. This recovery is secured in a couple of days, whether the homogenized and pasteurized product is held cold as cream or is made up into ice cream and then held. Moreover, the evidence thus far obtained seems to indicate that no condensed milk is needed to produce body when homogenized cream is used; in fact the addition of only a single quart of condensed milk to 10 gallons of 16% homogenized cream made an article possessing too much body. Ice cream made of 9 gallons of homogenized cream testing 16% fat, and 1 gallon of plain 18% cream, with sugar and flavor, proved superior in body, texture and in general creaminess to that ordinarily produced with 10 gallons of 18% cream and 2 quarts of condensed milk, both containing gelatin in equal proportions.

CONDENSED MILK

Condensed or evaporated milk is frequently used in ice cream making; and provided wholesome goods are used in not immoderate quantities it has a legitimate place therein. It increases the body and smoothness of the goods, without producing that extreme richness in fat which would be required of a normal cream to secure the same quality effect. Many ice cream-makers may find it to their advantage to purchase quantities of the evaporated milk which has been partially churned in the "breaking" process at the condensory. This milk is in every respect as pure and wholesome as is any condensed milk, but on account of these minute granules of butter is not sold on the open market. By pouring the evaporated milk through a sieve the granules will be removed, the loss will be insignificant and

the main product will be as valuable as though a higher price had been paid for it. Better yet, where the ice cream maker has access to a homogenizer the cans of partially churned or clotty condensed milk may be emptied and the contents run through the machine at a temperature of 170° to 180° with the effect of restoring to the article much or all of the qualities possessed by the normal and high priced goods. It goes without saying, however, that the so-called "swells," i. e., goods faulty because of fermentation within the can, cannot be thus used; and the semi-decomposed barrel goods, sometimes offered the trade, are also tabooed. Either may be a fruitful source of ptomaines. The use of such materials emphasizes the importance of thorough survey of each and every ingredient used in the making of ice cream and the real inefficiency of any examination solely of the finished product. Unquestionably the occasional use of such stuff has had much to do with the unfavorable attitude of some food control officials towards the use of condensed milk as an ingredient of ice cream.

THE SUGAR

Ordinarily cream is sweetened to taste when about one-sixth of its weight of sugar is added, making the finished product approximately 14% sugar. An 18% cream costs about 7½ to 8½ cents per pound, while sugar sells now at 5 to 6 cents per pound. Within bounds, sugar is certainly a pleasant adulterant. Sugar weighs about 15 ounces to the pint, or about 7½ pounds to the gallon. One gallon of water and 12 pounds of sugar will produce 2 gallons of simple syrup weighing 10 pounds to the gallon.

The addition of the usual quantity of sugar increases the volume of the cream between 9% and 10%. Sugar, used in the quantities ordinarily employed in ice cream making, acts as a slight preservative of the cream. At ordinary room temperatures a cream carrying the usual amount of sugar will remain sweet approximately one day longer than will the

same cream unsweetened. However, sugar is not present in a quantity which is sufficient to preserve the milk indefinitely; and it becomes sour and otherwise offensive very rapidly when once it starts on its downward career.

Maple sugar is rather soft and when added to cream settles into compact close masses and dissolves very much more slowly than does the common granulated variety.

THE FILLERS

STARCHY FILLERS

Wheat and rice flours and corn starch are still occasionally employed to give greater resistance to the body of a piece of goods made from cream low in butter fat. A rich cream does not need a filler; and it is a moot question whether a frozen substance carrying any appreciable quantity of such body giving material should be considered a true ice cream. It approaches a pudding in character and should be so called. Any one of these materials may be used for this purpose, though wheat flour is to be preferred to corn starch. Apparently because of the gluten thus introduced, the viscosity of the mixture is not materially lessened by the use of wheat flour. Rice flour seems still to meet with more favor, however, because of the fact that rice starch grains are much smaller than most others. Any of these fillers should be thoroughly cooked before being introduced into the cream, first being made into a very thin paste and then worked up into a greater and yet greater volume of cream, while hot. If not cooked prior to use, the starch grains are very much in evidence when the product is eaten, seeming like rough granules on the tongue. These materials added in too great quantity cause the mixture to become too heavy, in fact so soggy that a fair swell is difficult to obtain. Fillers never increase the swell and if used in excessive quantities lessen it.

EGG FILLERS

Eggs are not infrequently used, especially with the fancy ice creams, the so-called French or Neapolitan types. Unless the eggs are cooked, however, the increase of body or of smoothness is scarcely perceptible, unless the goods made are extremely thick with eggs. When cooked, however, into what is virtually a custard and then frozen, a greater body and smoothness is secured, together with a decided loss of volume. Eggs are seldom used in the plain goods and practically never in the cheaper grades.

RENNET FILLERS

This well known substance in some form and usually under some disguising name is not infrequently employed to give a greater body and smoother texture to lean creams. No larger quantity of ice cream can be obtained by the use of rennet, but if the cream is allowed to remain warm long enough for the rennet to coagulate the mass, and it is then cooled for a period and frozen, its body will be slightly firmer and its texture somewhat smoother than would otherwise have been the case. Rennet is the active principle found in some of the ice cream powders, especially those which require introduction into and thorough mixing with the cream for some considerable time before freezing. It has a very small place, if any, in commercial ice cream making.

THE BINDERS

GELATIN

Gelatin is a substance of animal origin. It is the water extractive of bones, etc., practically identical in character with the jelly-like mass which the cook expects to find in the pot after a soup bone has been boiled. Gelatin is prepared for use by first dissolving it in hot water, or, better yet, in a portion of the skim milk with which the over-rich cream is reduced. When this has been heated and stirred until entirely free from small lumps or clots of undissolved gelatin, it is quickly strained into

the batch of cream while hot and well stirred. A good and quick way to prepare this binder on a large scale is to put it into a milk can or pail with small top, to add the desired amount of skim-milk, and then to insert a hose or steam pipe and turn in live steam, stirring actively.

Gelatin has been used in commercial ice cream for a great many years and is still being used for the purpose of preventing the water, which is normally and naturally present to the amount of about 60% to 70% of the total weight of ice cream, from forming into disagreeable, spiny crystals when the goods have to be held for one or more days. When ice cream is freshly made, only the veteran ice cream maker whose taste is trained can distinguish that in which gelatin has been used from that made without gelatin; but after the product has been packed for 24 hours, that from which the binder was omitted will be found to have a coarse texture while that made with gelatin remains fairly smooth and agreeable. This difference continues to exist and, indeed, becomes greater with the lapse of time.

This substance is not in favor in many states, though its use in ice cream is allowed by the laws of Vermont. Controversy is still being waged as to the advisability of its use. Some maintain that the possibilities of its contamination during the process of manufacture are so great that gelatin is not a safe or fit substance to be used in ice cream making. Others deny the justice of this attitude and say that if such is the case, its use as gelatin on the table should likewise be forbidden. The fact remains, however, that practically everything which can be said against the use of gelatin from the standpoint of uncleanness can with almost equal force be urged against milk and cream themselves. It is occasionally contended further, that glue is used instead of gelatin in ice cream making. Even if this be true, it of itself does not furnish warrant for the exclusion of all gelatin, including that pure enough for family table use. The characteristic odor of glue

is largely that produced by the decomposition or rotting of the animal matter from which glue is later made, and its use in any food product whatsoever should be most heartily condemned. However, the fact that the clean and higher priced goods are in reality the cheaper to use, will act as a constant and almost automatic regulator in the matter of gelatin usage. From $3\frac{1}{2}$ to 4 pounds of the higher grade costing about a dollar will accomplish as much as will 6 or 8 pounds of the cheaper goods costing half as much again. The presence of gelatin does not appreciably affect the amount of the swell unless used in very considerable excess of any amount which the consumer would accept, when a smaller swell is secured. (See page 47).

GUM TRAGACANTH

Gum tragacanth is a material of vegetable origin and is very similar in its nature to the gum that oozes out of and hardens on the trunks of cherry and peach trees. It does not go into true solution in water. It is used in practically the same manner as is gelatin and for the same purpose. It possesses some advantages over gelatin, especially in being odorless. It seems too to be used by those who wish to be able to declare that their goods contain no gelatin. An exceedingly small quantity is sufficient to prevent the formation of coarse crystals. One ounce in chip or shaving form, when soaked and heated in a quart of water, will cause the entire mass to become very heavy and tenacious. If to this mass one and one-half quarts (three pounds) of sugar is added, about one and one-half quarts of gum tragacanth stock will be produced. Four tablespoonfuls of this stock is enough to use in one gallon, one quart in ten gallons of ice cream. If this amount of sugar is employed, the gum stock will remain usable for several weeks, in fact the amount of sugar used is almost enough to prevent the stock from spoiling at all. Gum tragacanth seems to be gaining in favor, either as such or in the form of some of the many powders that are on the market.

ICE CREAM POWDERS

Ice cream powders are being sold under a great variety of names, each implying that a special, creamy, velvety, rich product will inevitably be made as the result of its use. The active principle in most of the powders on the market, is either gelatin, gum tragacanth, or a mixture of the two, very finely pulverized and thoroughly trituated with from six to ten times its weight of powdered sugar. Rice flour, dry rennet and corn starch are also occasionally added to the mixture. Naturally these powders produce essentially the same effect as would the raw materials from which they are built; for catchy trade names are valueless in this respect. Many of these powders on being tested gave every indication of containing gum tragacanth, affording the glossy, slightly sticky condition to the finished ice cream which is characteristic of that article. Their chief advantage lies in the convenience attending their use, which precludes the necessity of a previous preparation of the stock and of its holding. When these powders are used, they are dusted on top of the mixture after it is placed in the freezer and well mixed. Because of their exceedingly finely divided condition, they spread quickly and evenly throughout the mass.

EFFECT OF BINDERS ON SWELL

Whenever the measurement of the effect of any particular material or condition was under consideration in the prolonged series of experimental trials, now under survey, enough cream was prepared to furnish material for all the batches to be run, and every other condition which could possibly have an effect upon the result was made and held just as nearly constant as it was possible to do. In this way only may the effect of any particular substance or treatment be determined. Thus in the following six groups of comparisons, the mix for the different batches was exactly the same in each group, and all the runs were made in quick succession.

Eleven freezings 18% cream, 48 hours old, sugar to cream 1 : 6; ice, salt and water 10 : 1 : 2; temperature of freezing mix-

ture 21° F. 50 revolutions of the freezer for 6 minutes, 200 revolutions until completed. Freezing finished in 9 to 11½ minutes. Temperature of mix 61°-63° F., room temperature 70° F.

Number of batches.	Gelatin used. %	Swell. %	Body.	Texture.
4	none	80. 60. 65. 60	good to fair.	fair
2	0.39	70. 60.	good	fair, good
2	0.78	60. 70.	good	good
2	1.54	60. 50.	heavy	gluey
1	3.03	50.	very heavy	gluey

Four freezings. Conditions as above save that 24 hours old cream was used. Mix temperature 55° F. time of freezing 10-12 minutes.

Number.	Gelatin used. %	Swell. %	Body.	Texture.
1	none	65	fair	fair
1	0.20	55	good	good
1	0.39	65	good	good
1	0.78	60	good	good

Still further and similar comparisons shown in less detail follow, conditions for each lot being identical save as relates to the use of binders.

Twelve freezings. 2 without binder, average swell, 68%; 10 with varying amounts of binder, average swell, 57%.

Five freezings. 1 without binder, swell, 50%; 4 with varying amounts of binder, average swell, 45%.

Eight freezings. 2 without binder, average swell, 55%; 6 with varying amounts of binder, average swell, 57%.

Four freezings (disc continuous freezer, 225 revolutions), 2 without binder, average swell, 38%; 1 with gelatin, 38%; 1 with gum tragacanth, 38%.

The following general averages of what the writer deems comparable results are submitted for what they are worth:

184 freezings without binders, average swell, 63% ; 37 freezings with varying amounts of binder, average swell, 55%.

ICE CREAM AT THE SODA FOUNTAIN

A few years ago the demand for the plain or merely flavored soda water gave way to the ice cream soda trade, and for some years this was consumed in large quantities. For such use the ice cream need not be rich in fat, but it does require gelatin or some other colloidal binder to hold the lump of cream in some form ; otherwise the jet and spray of soda scatter the cream into fine bits. The contents of a glass of ice cream soda in which no binder had been used in the cream, could be easily drunk as a gruel, but it could not well be eaten. The demand for ice cream soda, however, is on the decline, sundaes, college ices and fruit splits, etc., now being in much greater favor.

THE USE OF GELATINOID BINDERS

The writer has no financial interest whatsoever in the manufacture or sale of ice cream or of any of its accessories. His interest in the matter is purely that of the student of dairy affairs who desires to make as thorough a presentation of the subject in hand as may be and to treat all phases thereof as frankly and fairly as possible. He appreciates that some of the views he expresses in this connection do not accord with those of certain scientists, eminent in matters of food analysis, for whose opinions he has the utmost respect. He feels, however, that to omit or to evade a fairly full discussion of this important phase of the general subject would be an indefensible position for him to assume ; that a bulletin on ice cream making which took no cognizance of this moot question would be to that extent an unfinished production. Furthermore, he is fully aware that a considerable proportion of the officials in whose hands lies the enforcement of the food and dairy laws contend against the use of gelatin or other binders in ice cream. Yet, on the other hand, his own considerable experimental work with binders

in ice cream making (pages 46-48) and his observational study of the making of commercial goods and of the necessary conditions attending their sale and usage, lead him to appreciate that there is great force in the arguments advanced in favor of their use, more particularly as to their relationship to the keeping quality and to the "take-back" problem.

However, as with most disputed matters, there are two sides to the case. These may be presented as follows:

ARGUMENTS AGAINST THE USE OF GELATINOID BINDERS

The arguments against the use of gelatinoid binders are essentially five in number, viz.:

1. That they tend to conceal the age of the goods.
2. That they permit of a greater inflation or swell of the product.
3. That gelatin as such may be an inferior and unhealthful product.
4. That their use enables a warmer and therefore less safe holding temperature.
5. That it were unwise to permit the use of any material other than cream, sugar and flavoring matter.

1. *The concealment of inferiority and age.* It is now quite generally known that ice cream which contains no gelatin or other binder becomes granular and coarse. This condition is manifested at once upon firm freezing, becomes quite noticeable by the time the goods are a day old, and continues to increase as time goes on. Hence, in the absence of a binder, any granulation or coarse, spiny condition of the ice cream is evidence of its age; and this condition furnishes a constant, unavoidable and increasingly pointed notice to the consumer that the goods furnished him are not freshly frozen. The argument of those who contend against the use of binders on this ground is not based on the belief that they are of themselves necessarily harmful, though an inferior or positively unhealthful gelatin may be used. They hold that they furnish a means whereby the

manufacturer or dealer may sell an old article in lieu of a fresh one, one so old, in fact, as perhaps to induce ptomain poisoning, and that the consumer is afforded no means of knowing the age of the goods or of appreciating this possible danger unless, as required by some state laws, the presence of the binder is declared on the package. The prohibition of the use of all binders would tend to localize the industry, to induce more frequent freezings of smaller quantities, and, it is thought, in this way more effectively to safeguard the health of the public. (Confer counter arguments, pages 53, 54).

2. *The alleged increased swell.* It is contended¹ that the use of a binder tends to encourage the incorporation of a greater amount of air into the finished product than would or could otherwise be the case; that inasmuch as ice cream is purchased by volume rather than by weight, and hence the greater the swell the less the actual food value in a given volume, this constitutes a fraud on the consumer; and, finally, that anything which promotes such inflation should itself be considered an adulterant and be forbidden on that ground. This contention does not appear to be well founded. It is the opinion of several ice cream makers that the use of gelatin increases the swell. The advertisements of many ice cream powders make this claim. These opinions and claims, however, do not appear to be based on accurate observation, or upon experimentation wherein other factors influencing the swell were under careful control. That this argument is utterly fallacious is abundantly proven by the data displayed on page 47; and it may be remarked, parenthetically, that the opinion of the generality of larger makers is quite uniform that binders are of no effect in this connection.

3. *The inferiority of the binder.* There is no gainsaying the fact that a low grade gelatin may be used; that a material hardly better than or different from glue may be employed in cheap grades. It is conceivable that the material thus used

¹Marine Hospital Service, Bul. 41, p. 292 (1908).

may be positively dangerous to health. Indeed, competent authority states that pathogenic organisms are found in much of the gelatin offered the ice cream trade, a statement which, if correct, is an unanswerable argument against the use of brands thus contaminated. The argument, then, is that in the interests of the public health the use of a product open to this objection should be forbidden. Whether the use of all gelatin should be prohibited because some is faulty; whether legitimate milk products like condensed milk should be rejected *in toto* because some makers use putrid stock, is a moot point. However, carried to its logical conclusion the same argument would rule out the use of cream itself, since some cows are tuberculous, some milk products develop ptomain poisons, and others have been made the vehicles whereby typhoid and other fevers have become epidemic. This particular point can hardly be urged against gurn tragacanth, a vegetable product.

4. *The lower holding temperature.* An ice cream which contains no binder requires a somewhat lower temperature to hold it in edible condition than does a piece of goods, like it in all other respects but containing a binder. The unbound goods must be held at 18° to 20°, while the bound goods are firm enough to dish well and be palatable at 20° to 24°. The higher the temperature, the greater the likelihood of bacterial development. Hence, the use of any material which will tend to raise the holding temperature is decried lest the public health become endangered. (Confer counter arguments, page 53).

5. *The difficulty of adequate food control.* The final argument may be termed the administrative one. The contention is that it were unwise to admit materials other than cream, sugar and natural flavoring lest abuses arise; that competition between and the greed of makers, not to speak of the demand in certain quarters for a cheap product, would tend to debase the goods, perhaps to such an extent as to make them unhealthful; that to allow the use of any substance other than the natural and necessary ingredients would be to invite a maker to employ

whatever materials he chooses and to apply the term ice cream to any cold substance whatsoever, whether containing milk products or not. It is the appeal for safety, the refusal of the inch lest the ell be taken.

ARGUMENTS IN FAVOR OF THE USE OF GELATINOID BINDERS

Some very pointed arguments may be advanced upon the other side. The question may be asked at the very outset, "Why are gelatins or other binders used in ice cream making?" Not for the purpose of inflating the product with an undue amount of air, for this they will not do, the contention as indicated under paragraph two on the previous page to the contrary notwithstanding (see page 47); not for the purpose of cheapening the article by adulteration since the materials used for this purpose cost several times as much as does cream. They are used for four reasons:

1. The prevention of the coarse granulation or crystallization of the watery portions of the cream.

2. The maintenance of a creamy, palatable condition.

3. The discouragement of the return of unused goods.

4. The regulation of trade.

1. *The prevention of granulation.* That a gelatinoid binder partially prevents the granulation of the goods is conceded by all. If no harm is done the dealer or consumer, such prevention is clearly in the interests of all concerned. That in the opinion of some harm is done, is evidenced by the arguments advanced on pages 49 and 50.

2. *The maintenance of condition.* It is no easy task to hold an article at a temperature 50 to 75 degrees lower than that of the surrounding atmosphere; yet at practically every hotel, restaurant and soda fountain this attempt is being made. With so many attempts there are bound to be numerous failures. If the ice cream does not contain some substance which serves to maintain it in a fairly firm condition when its temperature rises, it becomes mushy and unsaleable, sales are decreased, a legiti-

mate demand upon the part of the customer is not met, and all interests suffer. The writer deems the argument advanced against the use of a binder on the ground that the unbound ice cream requires a lower and therefore a safer holding temperature (see page 51) far fetched, a quibble over a mere three or four degrees of temperature, located moreover at a thermometric point far below the customary and approved temperatures for holding most other food products of a comparable character; fresh meats for a short carry (comparable with ice cream) being held at a temperature of about 30°, fresh poultry, fish and game at 25° to 28°.

3. *The return of unsold goods.* Under conditions such as those indicated in the last paragraph the retailer insists that the manufacturer take back unsold goods, and, in order to hold his trade, the latter is obliged to comply with his customer's request. This returned cream, sometimes a little, sometimes much at a time, is mixed with new stock, refrozen and sent out again. Perhaps some of these mixed goods are returned unsold and unsalable, and portions of the first make are again refrozen and sent out for the third time. Freshly frozen lots containing a small quantity of refrozen goods cannot be distinguished from those made solely from fresh stock. It is quite conceivable that the ice cream output from a factory doing such a take-back business may be contaminated for a month or even for an entire season. There is every reason to believe that these are conditions which preeminently favor putrefactive decomposition and the development of ptomaines. To prevent the use of a binder which will aid to maintain the condition of the cream and to favor its comparatively fresh usage is to encourage the practice of refreezing returned creams; whereas its use serves to reduce to a minimum the practice of returning and refreezing goods. The true age of an ice cream is measured by the age or, rather, the condition of the ingredients of which it is made, not by the length of time since it was last frozen.

4. *The regulation of trade.* It is urged that the ice cream business should be kept a local industry; that the nature of its product is such that large establishments are impracticable. There is perhaps room for argument here, although the point does not appear to the writer to be well taken. However, even on the assumption that the trade must remain localized it should be remembered that there is probably no other large industry, the demand for the product of which fluctuates so arbitrarily and so absolutely independently of man's control; that the demand for frozen dainties is as fickle as the wind, that it may increase ten-fold in less than as many hours of hot weather and cease as suddenly when the wind shifts; that the manufacturer must be prepared to supply this varying demand and to hold a surplus to be supplied at a moment's notice; and, finally, that for purely business reasons no ice cream maker will store goods any longer than he needs to, but on the contrary, will sell them as quickly as possible. Furthermore, it should be remembered that anything which tends to prevent reasonably long shipments as strongly tends to scatter the manufacture, locating it in the hands of many men, often of limited ability, means and equipment. This would certainly result in the reversion of the industry to unskilled workmen and insanitary cellars, a condition which is obviously objectionable; and finally, that such a reversion would tend to increase the cost of the product to the ultimate consumer and the expense and difficulty of adequate supervision by health authorities.

VI. TYPES OF FREEZERS

The many kinds of freezers on the market may be roughly divided into four classes or types. There are however several variants in each class.

Vertical-batch-ice. This type is the most common of all, being represented by the ordinary upright batch freezer, the kind that has been used for many years. With this type the cream is placed in a large can provided with a dasher and

is set, preferably before filling, into the wooden tub. The whole is then put into position and attached and the space surrounding the freezing can is filled with crushed ice and salt. A ten-gallon freezer will require for its first batch approximately 60 to 70 pounds of ice and from 5 to 6 pounds of salt. Following batches may be run with less fresh material, due to the fact that the machine is now cold and provided with considerable ice not yet melted.

Vertical-batch-brine. The distinctive feature of this freezer is that though vertically placed it is high enough above the floor so that the finished ice cream is drawn from the bottom without stopping the dash. In place of a heavy wooden tub and ice, the freezer proper is surrounded by brine. The rate of freezing in this as in other brine freezers is controlled by the temperature of the brine and the rate of its flow through the machine.

Horizontal-batch-brine. This type of freezer is quite similar in some respects to the one previously described, the chief difference being that it lies horizontally or nearly so. It is surrounded by brine, the finished ice cream being drawn from the lower side of the lower end. This also usually has a small tank immediately over it or close at one side, in which the next succeeding batch is prepared during the progress of the freezing process. This, like the preceding one, though not a continuous machine, may be worked almost continuously.

Horizontal-continuous-brine. The evolution of this machine marked a distinct breaking away from the older conceptions of ice cream freezer requirements. In this mechanism the cream flows in at one end of the machine, and the finished ice cream out at the other. The freezing is done by the passage of brine through the discs which revolve rapidly in the cream as it is being crowded to flow from one end of the machine to the other. This type of machine is open and in some respects offers advantages not possessed by the closed machines, especially in giving the operator opportunity to use the thermometer more

accurately in the freezing process, which is a distinct advantage (page 30). This type of machine is made in different sizes with both single and double set of discs.

It should probably here also be noted that the use of a brine freezer is not restricted to the plants having artificial refrigeration. The brine for circulation through discs or around the freezer may be provided either from the large brine tank of the artificial cold storage system or may be produced at will by the mixing of salt, ice and some water in the brine box which accompanies the machine if desired. This brine is then forced by a small pump to circulate and do the work of freezing.

Automatic freezer. This little freezer, if it may be called such seems to be a device gotten up principally to sell, its chief claim for merit being that it does not require turning while the cream is being frozen. According to directions accompanying the instrument now most conspicuously advertised, we learn that it is important to "keep the glass jar on ice until ready to fill." "Use thick cream and be sure to have it ice cold while whipping. After whipping the cream thoroughly, whip into it the other ingredients which have previously been prepared, then pour into the jar and pack quickly in the ice while jar and cream are still ice cold." "Pack in a wooden pail or tub, using one part rock salt to three to five parts of finely pounded or chipped ice. When snow is available it can be used with equally good results. In either case use plenty around and on top of jar. Cover pail with blanket or rug, and set in a cool place to facilitate freezing and save ice. Three hours in the ice pack is usually about right."

Upon trial it was found that when the cream was rich enough and had been cooled low enough and beaten thoroughly enough before putting into the glass freezer, the resulting product was fairly edible; but when the whipping had not been thoroughly done, the resulting "ice cream" was found to have crystallized into a mass extremely coarse and unpalatable flakes even though the mix had been made of very expensive

material. Naturally the fact that both the cooling and the whipping of the cream can be done far more quickly and easily in an ordinary hand freezer than elsewhere, is not stated in the claims for this tool. In the opinion of the writer, this contrivance merits an exceedingly small place, if any at all, even in the small kitchen. If one will exercise one-half this care with cream and freezer, cream may be well frozen in ten to twelve minutes with the ordinary hand freezer (page 59).

VII. THE FREEZING PROCESS

The freezing mixture almost universally used consists simply of common salt and ice. Salt is deliquescent, that is to say, has an affinity for water and attacks the ice to procure the water for which it craves. However, any change of any body from the solid to the liquid state, no matter what the body is, is accomplished only by the absorption of heat. Ice is melted by heat; butter melts on a warm day; iron is melted in the fierce heat of the convertor. Now the ice in the freezer is melted by heat, and this heat is obtained where it can be got most readily; some from the air, some from the surrounding walls of the freezing tub which, being made of wood which is a poor conductor, permits but little to be obtained from that direction, but principally from the relatively warm cream-sugar mixture within the freezer. There are several other substances which could be used in place of common salt to produce this same effect, as for example calcium chlorid and ammonium chlorid; but these possess several natural disadvantages, not to speak of their greater cost, which preclude their general use.

In the following discussion of freezing conditions, the writer has in mind more particularly the ordinary upright 40 quart batch freezer, such as will probably be found most serviceable to the creamery men of Vermont.

SALT AND ICE

A fine salt dissolves much more rapidly than does a coarse salt and as a result cold is more quickly produced. Its use

is not common, however, for the reason that it is usually too high priced, and further that it tends to form crusts and bridges which prevent the ice from settling and fitting around the freezer. Coarse barrel salt, such as is ordinarily used for stock purposes, is satisfactory when used with caution, especially with small brine freezers, and it is considerably cheaper than the crushed rock or the ordinary flake ice cream salt. The pulverized rock salt, however, is decidedly to be preferred for packing purposes despite its higher cost, for it rattles more thoroughly through the crevices of ice, and does not melt so rapidly and thereby continues the cold for a longer time.

The ice should be broken quite fine, thus allowing more surface exposure for the action of the salt and causing more rapid freezing. Coarse lumps frequently cause trouble by cramping against the freezing can. Where it is difficult or impossible to break the ice fine, it will be found especially convenient to pour water around the freezer at the start. This tends to float the lumps and to prevent the grinding and snubbing so often noticed, especially with hand freezers. Ice that has once been used for freezing may well be used for packing purposes, but, having lost its many sharp points and edges and at times too its "specific cold," it is not as well adapted to freezing purposes as is fresh ice. White ice, i. e., snow ice, because of the larger amount of air which it contains, melts more slowly than does the clear ice and for this reason is materially better for use in packing and shipping.

Proportions of salt and ice. The proportion 1 to 3 is frequently advocated in cook books and other similar literature, and with this statement is usually linked the recommendation that coarse salt be used. This large proportion is not found especially inconvenient in small freezers, because of the coarseness of both the salt and the ice, and the fact that a large portion of the salt does not dissolve, quantities being found later in the bottom of the freezer. Finer ice, by permitting more rapid freezing and more thorough and economical use of the salt,

makes the proportion 1 to 12, 1 to 15, or even one as wide as 1 to 20 thoroughly ample, provided one-third of it be placed fully half way from the bottom and the other two-thirds nearly on the top of the ice, so that as it dissolves it must trickle over the pieces located lower down and so do work all the way to the bottom. The application of large quantities of salt near the bottom of the freezer is very largely a waste. The proportion 1 to 15 will be found thoroughly serviceable, provided the other features have been looked after.

DURATION

The duration of the freezing process, or, in other words, how long it takes, depends on the temperature of the cream and the brine, on the proportions of salt and ice which are used and upon their fineness, on the closeness of contact, and, finally, on the amount of sugar used in the cream. Sugar usage, however, is usually a nearly constant factor, and hence its effect is uniform. If the cream "mix" is placed in a common tub freezer at 60° to 65° it requires some four to eight minutes to cool to the whipping point, and five to fifteen more to finish the freezing process. It is of course possible to cool it quicker, in which event the cream passes through the whipping temperature so rapidly that thorough beating is impossible. If it is put into the freezer at 34° to 36°, it may be frozen in eight to ten minutes and ample time allowed for whipping.

The rate of the melting of the ice is governed in part by the size of the salt and ice which are used. The proportions employed also affect the temperature of the freezing mixture. The proportions often recommended are 1 of salt to 3 or 4 of ice. This is more than is needed, in fact the proportion of 1 of salt to 12 to 15 of ice will be found ample when one-third of the salt is placed two-thirds the distance from the bottom and the remainder is put nearly to the top of the ice. The proportion of 1 to 40 will freeze cream, if given time enough. On several occasions a gallon freezer with 2½ quarts of mix was

frozen, using 10 pounds of ice (actual weight) with one-half a measuring cup ($3\frac{1}{2}$ ounces) of fine salt. This extreme is impractical; but so is the proportion 1 to 3 or 1 to 4 wasteful. Fine salt dissolves more quickly than does a coarse salt, thus freezing the cream in somewhat less time.

Another item of procedure usually neglected, especially by small makers, is that of adding water to the salt and ice in order to hasten the freezing process. When the ice and salt are dry, a large part of the outer surface of the freezing can is exposed simply to cool air, which, as is well known, is an exceedingly poor conductor of heat. The heat contained in the cream can be effectively withdrawn only at those points where an ice fragment lies against the freezer can, here a spot and there a streak, with air circulating between, until such time as there has accumulated a sufficient amount of water from the melting of the ice to form a close fitting conductor for the heat; whereupon the cream freezes promptly. Instead of starting to freeze the cream at the temperature of 60° or 70° , as is often recommended (in cook books), in order that the ice may be melted to form water, it is much better, if it is desired to hasten the freezing process, to start with a colder cream and to pour a quart of cold water around a gallon freezer, or some two gallons around a ten gallon freezer. This is especially true when a coarsely broken ice is used. This is the reason that ice cream so often freezes more quickly in summer than it does in winter. The addition of water thus produces a brine of the temperature of 20° to 22° . It is especially serviceable when snow is used instead of ice. To secure the best all-round results, cream that is put into the freezer at 60° to 65° should not be frozen in less than 20 minutes, and it need not require more than 25; if started at 45° , from 12 to 16 minutes are employed, while if at 34° to 35° , it may be well and smoothly frozen in 8 to 10 minutes; in fact the conditions are more favorable to success in the last than in the first instance.

When only a single batch of ice cream is to be made, and the facilities for holding the cream cold are meagre, the cream "mix," ready to be frozen, may be put into the freezer the night before, packed with ice without salt, and allowed to stand over night, ready for the morning's freezing. It will be found that this thorough chilling immediately prior to the freezing aids very materially in securing an ample swell, a good body and a smooth texture; and that the actual freezing may be done in a short space of time, say 8 to 10 minutes.

SPEED

It is very convenient in freezing ice cream to be able to use two quite different speeds. This is especially the case when it is necessary to freeze a cream which is started at ordinary room temperature, 68°. When this condition obtains, the freezer should be turned comparatively slowly when the internal fixtures have a motion equivalent to say 50 to 60 revolutions per minute for some five to eight minutes, or even much more slowly as indicated on the next page, until the temperature of the mix is below the churning point, or has reached, say, about 40°. Then the speed should be increased until the internal fixtures have a motion equivalent to about 175 to 200 revolutions per minute. This more rapid motion is necessary for the proper beating or whipping of the cream during the short time that such action can avail (see pages 28-33). If turned slowly throughout the entire process, the swell is very small and the texture coarse. If turned rapidly from the outset there is great danger of churning. The discs or other cooling apparatus of the continuous freezers which have a constant speed, should be well cooled before the cream is admitted.

CREAM CHURNING IN THE FREEZER

Not infrequently, especially when ice cream is made at home, lumps of butter form in the cream or on the dasher. This

is caused by the warm, and often rich, cream being agitated too rapidly in the freezer before it has had time to cool past the churning point. If the cream is to be put in warm or at least not real cold, the turning should be relatively slow during the first eight to ten minutes. There is, furthermore, nothing to be gained by rapid turning at the outset. One revolution of the crank every half minute is ample for eight to ten minutes, or until the first indications appear of the machine laboring or running harder, at which time it will be understood that the mixture has reached that temperature where it may be whipped and retain some of the air beaten into it. The speed should then be increased to a lively rate, which is maintained until the freezing process is nearly finished. Churning then may be avoided by less active early agitation, or by having the cream cold upon the start. The addition of water to the ice and salt may also be of value in hastening the cooling process, thus shortening the period of time when churning can take place.

THE FREEZING POINT

In ordinary practice the time to stop the freezer and to remove the dasher is when the young ice cream has reached the consistency of extra heavy condensed milk. The temperature at this condition is approximately 28° to 27° . If turned long after reaching this condition, some of the air, even as much as half of that which has been previously whipped into it, will be gradually worked out, so that a much less quantity of finished product will be obtained. In this semi-liquid condition, also, it is in the best form to transfer without loss of volume. In this connection see statement on pages 28-38 and in particular the diagram on page 30.

EFFECT OF THE FAT CONTENT ON THE FREEZING POINT

The exact temperature at which milk or cream becomes frozen is not in any way influenced by the fat percentage. A rich cream freezes at no higher and at no lower temperature

than does a thin cream; but it will appear heavier and be firmer at any given temperature. The reason for this is found in the high freezing (solidifying) point of the fat globule. Obviously a constituent which solidifies at relatively so high a temperature can have little or no effect on the freezing point of a material which hardens at relatively so low a point; and this is true regardless of the amount present, whether the fat content is large or small.

EFFECT OF FILLERS ON THE FREEZING POINT

Fillers, such as flour, starch, etc., which do not go into solution, have no influence upon the true freezing point, but, like the fat, afford a firmer body for a given temperature, because of their generally firm qualities. Such materials as egg and gelatin, however, that enter into a more or less true solution, depress the freezing point, but to so slight an extent on account of their extremely high molecular weights that they are of no consequence in this respect. No difference could be detected in practice in the temperature or time of freezing which it seemed safe to ascribe to the use of these colloidal materials.

EFFECT OF THE SUGAR CONTENT ON THE FREEZING POINT

Sugar goes into true solution and has a low molecular weight as compared to egg or gelatin. It depresses the freezing point very materially and uniformly in proportion to its presence. Similarly the milk sugar, a normal milk constituent, being in true solution, causes milk to freeze at a lower temperature than does pure water. Ice cream sweetened to average taste contains approximately 14% added sugar, and has a freezing point of about $28\frac{1}{2}^{\circ}$ F. When ice cream has frozen to the proper consistency for removing from the freezer to the packers, its temperature is about 28° to 27° . The following table, prepared from the data obtained at this station, using a Beckmann's freezing point thermometer graduated in $1/100$ of a degree, may

be of interest as showing the freezing points of different sugar solutions.

Material	Observed freezing point
Plain skimmilk	31.03° F.
5% solution sugar in skimmilk.....	30.40
10% " " " "	29.70
14% " " " "	28.60
25% " " " "	27.07

The more sugar there is in any ice cream, the lower the freezing point and the more difficult it is to hold it frozen hard. Sherberts require more sugar than does ice cream, and hence are almost liquid at 21° to 22° when ice cream would be only mellow.

TRANSFERRING

So far as possible all transferring and handling of the finished product should be done while it is still in a fresh condition, for it can then be managed easily and without loss, while if packed away and hardened and, later, re-dished into the pint, quart and gallon containers, a loss of volume results. From six to six and one-half gallons of "mix," making ten gallons of finished ice cream, will fill ten gallons of orders if handled while fresh, but it will fill only nine to nine and one-half gallons of orders if dished 24 hours later. Taking all things into account, a loss of about 10% must be expected if the ice cream is molded or packed into small containers after it has once been allowed to set.

HOLDING

If but a single batch of ice cream is made, it can be most easily and economically held by merely scraping the dasher, packing down the ice cream, covering the can, drawing away the water and repacking in the freezer tub with fresh ice and salt. If more than one batch is to be run, it should be transferred as soon as convenient into cans which have pre-

viously been well cooled. If they are filled when warm and then set into the freezing vat, there will be some loss of volume and coarse crystals of ice will form on the bottom and around the walls of the cans. If water is allowed to surround this holding can, the ice cream will harden more uniformly and more quickly, but will not become so firm as it will finally become if the water is drawn away and a fresh quantity of salt and ice is packed about it.

RE-HARDENING ICE CREAM

Ice cream that is being held and which has become weak from rising temperature should be re-hardened with great care; for if the mass has become materially melted and then is re-hardened without being run through the freezer, large water crystals will form causing the mass to become coarse, spiny and very unpleasant. Then, again, there is great probability that some of the skim milk portion containing large quantities of sugar has settled to the bottom, and that the portions richer in fat have moved upwards; in which case the bottom few inches of contents will be found when it reaches the consumer, to be but little better than a lot of sweetened ice crystals. The mass of re-hardening ice cream may be well mixed with a heavy spoon while being frozen. This procedure prevents this settling out. However, at best such re-hardened ice cream will become relatively coarse grained and spiny, and a considerable loss in volume will occur.

RE-FREEZING ICE CREAM

The taking back of melted ice cream as a practice should be most emphatically discouraged, because of the dangers which arise from the possible decomposition of the product and consequent ptomain poisoning and from the danger of scattering contagious diseases. However, ice cream that for any reason has happened to melt while still new and fresh enough so that there is no danger of decomposition having started, may be refrozen

by again placing it in the freezer and treating it as an ordinary run. This second freezing, however, requires a considerably longer time than does the initial effort, because of the air it contains; and, moreover, it is liable so to increase the amount of air contained in the cream, as to cause it to become very fluffy and weak bodied. Such thawed ice cream, if not old, may be mixed with the ordinary new "mix" and run out therewith without likelihood of this difficulty.

BUTTER FROM ICE CREAM

Ice cream which has melted and soured or gone "off flavor" need not be an entire loss. If such stuff is returned to the factory the butter-maker can, by mixing it with a small quantity of skimmilk and souring it yet more, churn it, and, by washing the butter rather more and salting it a little more heavily than usual, produce a butter, which, though not first class, still has market value. It would not be wise to put such a lot of ice cream, even though quite fresh, into the usual batch of cream for butter making, for the reason that the sugar contained in the ice cream will often ferment enough to give the entire batch a sharp, unpleasant character, and the flavor used in the ice cream will cling to the butter. If the returned ice cream is quite bad, it may, if there is enough of it to pay, be churned out with the least possible amount of labor and the product sold as packing stock, eventually to find its way, with country butter which is no better, into the renovating establishments. This is one method of preventing the total loss of returned goods.

FAT CONTENT OF DIFFERENT PORTIONS

It is the custom at many ice cream parlors to secure five, six or ten gallon cans of ice cream and to hold them until they are emptied by use. Occasionally, in case of cool weather, it requires two, three or more days to empty them. Such conditions favor the weakening of the ice cream, because of warm-

ing. It has been found by means of systematically planned tests, that the fat in such semi-melted ice creams rises, the extent of the process depending more particularly upon how nearly melted the ice cream becomes and how long it stands. In one test, after the can had stood for one week, probably one-third of the time in a rather mellow condition, the top portion of the contents tested 28% fat, the middle 15%, the bottom 5.5%. Another trial, in which the cream was held frozen thoroughly hard for a week, no difference whatsoever was found in the test of different portions taken from top, middle and bottom. A third trial afforded the following results: 22%, 14% and 8%; another, 10%, 8% and 6%; and yet another, 12%, 8% and 4%. It mattered but little whether there were gelatin or gum tragacanth in the mixture, the fat rose with apparently equal ease if the temperature were allowed to rise. This was especially the case with fruit ice creams. The heavy fruits and syrup settled quickly, even when gelatin was present. The attention of the writer, who at that time had to do with the enforcement of pure food laws, was first called to this point by a party who maintained that the fat disappeared upon standing, and that ice cream four or five days old did not contain as much fat as it did when freshly made. The deduction of course was erroneous; but practically, for the consumers of the contents of the lower third of the can, it was a fact. The fat had disappeared, so far as they were concerned. But it was not a case of disappearance, but of transference, of creaming. When ice cream weakens, its fat will rise and be "dished off" to a large extent with the earlier removals from the can, so that by the time the bottom of a large can is reached, some days having elapsed, a poorer grade of ice cream is found. Pure food inspectors when drawing samples for analysis should make note of the age of the ice cream, as well as of the perpendicular location in the can whence the sample is drawn. Inasmuch as the cream can rise very little if at all even under the most favorable conditions on homogenized milk or cream, it is highly probable that no dif-

ficulty will be experienced when cream is used which has been thus modified.

SHIPPING

In order to secure good shipping qualities the goods should be thoroughly hardened—at about 16° F—clear to the core for some hours before being shipped out. Otherwise the shipping ice, which should be required only to hold the ice cream from warming, is also asked to aid it in its cooling. Ice for shipping should be broken only to a medium fine grade so that it will not melt too rapidly, and it should be not too liberally provided with salt. White ice is best because it will “hold the cold.”

VIII. FORMULAS

It is not intended that this bulletin should be in any sense a book of recipes, for such may be found by the hundreds in cook books, ice cream freezer advertising matter, gelatin booklets, etc. It may be well, however, to print a few of the more common and approved formulas and to exhibit one or two special, uncommon, but desirable, recipes.

Vanilla ice cream. This is doubtless the most common of ice creams. To make 10 gallons one should use about 50 pounds (or 6 gallons) of aged 18% cream, (or 5½ gallons of cream and 1/2 gallon of condensed milk) about 1/6 that quantity or 8 pounds of sugar, 3 to 4 ounces of vanilla extract; and 3 to 4 ounces of gelatin, or 1 quart of “gumstock” (see page 45), if a binder seems called for. To make a single gallon of ice cream, 2 quarts (4 pounds) of 22% cream, 7/10 pounds (11 ounces) of sugar, 1½ tablespoonful of vanilla extract. There is little or nothing to be gained by the use of gelatin in ice cream made at home for immediate consumption. The sugar should be thoroughly dissolved in the cream before the freezing process is started, although under many conditions the time and amount of agitation given before the cream freezes is sufficient to dissolve and to mix in the added sugar. Experience only can indicate the safety

of this point to the maker. The flavoring may be added at any time before the mass starts to freeze.

Vanilla ice cream is especially accommodating, in that though of itself it is one of the most popular of flavors, its flavor is yet so delicate that it easily gives way to other and stronger ones, like coffee or chocolate; so that if but a single quart or gallon of coffee ice cream is ordered, it is a not infrequent practice in the trade to mix a small quantity of the desired flavor with a sufficient quantity of vanilla ice cream, and thus to accommodate the consumer and relieve the dealer of certain embarrassments. Or if, say, vanilla, coffee and strawberry ice creams are desired, the stock for the entire three kinds are made up as one batch, then used first as vanilla to the extent desired, then as coffee, and then as strawberry, one after the other, all from one and the same vanilla mix and without washing the machine, and usually to the entire satisfaction of all concerned.

Vermont maple ice cream. The flavor of the maple is one of the most delicate and popular flavors in this country. Vermont has long enjoyed an enviable reputation for the quality of its maple goods. Much study has been given to the making of this product with the result that nowadays large quantities of very light colored and delicate flavored sugar are being produced. However, this light colored and delicately flavored sugar is not of much use in making ice cream, for the reason that after it has been added to the cream in sufficient quantity to produce the desired sweetness, the maple flavor cannot be distinguished, owing to the fact that the natural flavor of the cream has thoroughly smothered and obscured it. The dark brown, indeed strong flavored, maple sugar (it must not have been burnt) is by far the best kind for making maple ice cream. The quantity to be used will vary with the strength of its flavor. If it be very strong, only about 75 to 80% of the total amount of the sugar used need be of the maple variety; or, in other words, the flavor of the cream may be built up with strong flavored maple sugar, and the sweetening then finished with common granulated sugar.

Maple sugar as produced by Vermont farmers is very variable in strength of flavor. When a milder flavored sugar is used, more will be required. Whenever a new lot is secured, the proportions of that particular lot required to produce a desired effect should be noted. No artificial or imitation flavor has yet been secured which even approaches in quality the natural flavor, and no cheap tricks should be attempted with this product. Clean sweet cream sweetened with pure maple sugar, and no other flavor added, and this properly frozen, will produce an ice cream of the highest quality. The proportions used should be much as in the vanilla goods. To make a 10 gallon batch are needed 6 gallons (50 pounds) of 18 to 22% cream (or the cream-condensed milk alternative shown on page 68), from 6 to 8 pounds maple sugar varying according to taste, judgment and experience, and, if desired, 3 to 4 ounces of gelatin or 1 quart of gum stock. For small gallon batches may be used 2 quarts (4 pounds) of 22% cream, from 9 to 11 ounces of maple sugar, and enough common sugar to complete the sweetening.

Coffee ice cream. This flavor is justly popular. When desired in only small quantities, the coffee flavor may be mixed with ordinary vanilla ice cream and in any desired quantity. Where it is made in large quantities, the coffee flavor may be introduced to the cream in any one of several ways, although the most convenient and business-like one is by using a stock coffee flavor. The writer has yet to see a commercial coffee flavor which approaches in delicacy that which may be made in any kitchen, though the cost of the latter will be somewhat greater. In a small way the following has been found an exceptionally satisfactory way of making the stock flavor. Ten rounding tablespoonfuls of high grade coffee are placed in one and one-half quarts of cold water. This is promptly brought to boiling and boiled vigorously for 5 minutes. It is then strained through several thicknesses of cheese cloth. To this liquid are added 2½ quarts sugar, which is dissolved and the whole mass brought to a sharp boil. This will produce about 2 quarts of coffee syrup,

enough to flavor about 10 gallons of ice cream. Coffee flavor made up into syrup in this manner, and put into fruit jars, even when left open, will keep almost indefinitely and be always ready for use, either as flavoring or as a dressing for coffee sundaes. If simple coffee is used as flavor, care should be taken that it is strong, so that too much water shall not be introduced, and that it is well cooled before being added to the cream. Whichever of the above methods of making the syrup is used, the added water will be partially frozen out into crystals upon standing.

Another and less satisfactory way is to make the coffee, using a portion of the cream instead of water. This must be cooled and then added to the main charge. If the entire mass of cream is heated it must remain in ice water for 12 to 24 hours before use, if a smooth ice cream is to be secured. In case a darker color is desired than the syrup will naturally afford, it may be secured by the addition of about 2 to 3 ounces of caramel (burnt sugar) to a 10 gallon batch. In regular work, however, a prepared commercial stock flavor will doubtless be found preferable to a home made flavor. The proportions of materials to be used are much as in vanilla cream-making, save that less sugar may be needed, the amount to be withheld being proportioned to the amount used in the added coffee syrup. If this amount is known the calculation is simple; if not, experience and judgment must be used as a guide.

Chocolate ice cream. When this flavor is desired in small quantities only, it may be produced by adding the chocolate stock or cocoa, previously melted and dissolved in a little sugar and water, to a finished vanilla ice cream. This, when well mixed, serves the consumer well without causing waste by holding several kinds on hand. Cocoa may be used in a small way, but the cakes of bitter chocolate will be found more serviceable in larger work. The bitter tang is covered over by the smooth character of the cream.

For 10 gallons of ice cream, about 1 quart of a chocolate stock may be used made essentially as follows: $1\frac{1}{2}$ quarts water,

2 pounds bitter chocolate, shaved fine, and 4 pounds sugar. Then chocolate is put into a sauce pan and a little water added. The mass is slowly heated, worked into a smooth paste, more water is then added and the working continued until the mass is smooth. Half the sugar is then added; the mass heated and again it is worked smooth. Then the remaining water is added, the mixture brought nearly to a boil and the remaining sugar added. It is then stirred and brought to a boil, care being taken not to allow it to scorch. The finished product is then poured into fruit jars for future use. In addition to the chocolate flavor, about 3 ounces of vanilla extract, and if desired, a half ounce of cinnamon extract may be used. The color will need be deepened for some trades by the addition of from 1 to 1½ ounces of caramel. The proportions of material used are much the same as in making vanilla cream save that as in making the coffee goods the sugar usage is lessened on account of the sugar in the chocolate stock.

Fruit ice creams. Probably the strawberry is the most popular of the fruit ice creams. The bulk of the commercial product is made in the same manner as is a plain ice cream, with the addition of a small quantity of color to give the strawberry effect. If preserved strawberries are used, they should be added after the ice cream has become partially frozen so that the heavy fruit sirup and the berries will not settle to and remain at the bottom. If fresh fruit of any kind is to be put into the cream, it should be well chopped or crushed and sugar added to it some time before using. It is then put into the cream after it has become partially frozen, in order that the acid of the fruit shall not coagulate the cream, as might be the case if added while it is warm.

Buttermilk sherbet. This new dish has merit and should become popular, especially in warm weather. It is made very much as are other sherbets, except that fresh, tart buttermilk is used in place of water, no lemons or other acid bearing ingredient being required. Made in a small way the following recipe has been found to give excellent results: 2 quarts fresh, tart butter-

milk, $1\frac{1}{4}$ pounds sugar, one large orange or two small ones, 3 teaspoonfuls gelatin. It is frozen in the same manner as is ice cream, save that no attempt is made to increase its volume materially. This sherbet is so rich in sugar that it will melt at a relatively low temperature, and, consequently, it will often be found slushy if held at the ordinary holding temperatures for ice cream.

Other kinds. Combinations almost without number may be prepared. Recipes for such may be found in many places, with directions for their preparation. In this connection it is of interest to note that almost anything of a cream or milk nature which is of pleasing taste when hot, is likewise relished cold. It should also be remembered that the flavor of a frozen article is much less apparent than is that of a warm one, so that in flavoring an ice cream to taste, the unfrozen liquid should be made more highly flavored than is desired in the finished product.

IX. MISCELLANEOUS CONSIDERATIONS

THE MODIFICATION OF CREAM FOR ICE CREAM MAKING

Creams of certain definite fat contents have been recommended in the preceding pages for specific purposes. Now all creams are not alike. Some are lean and some are fat. The same cream delivered by the same party may carry decidedly different fat contents, today and tomorrow. It is highly desirable that a uniform fat percentage be maintained in the cream used in a given factory. Hence, there should be means at hand for standardization and the method of the attainment of that end should be clearly understood. This proposition has been worked out and modifying cream to standard strength is now an every-day operation in many commercial plants.

DIRECTIONS FOR MODIFYING CREAM

The simplest and most accurate method of modifying cream or milk to any desired standard of butter fat is that developed by Pearson. This method, discussed below, is applicable not

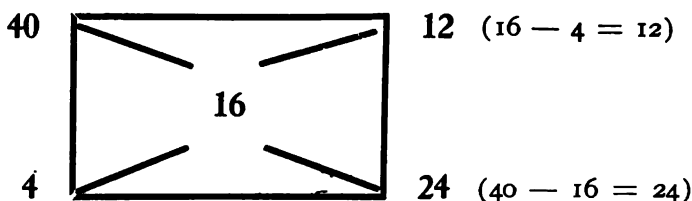
only in ice cream making, but in market milk and cream work generally.

Example 1. Given a 40% cream and a 4% milk, to be mixed to produce a 16% cream. The amount to be used can be determined very readily by the following procedure:

(1) Subtracting the figure representing the desired quality from the known cream fat percentage to obtain the amount of milk to be used.

(2) Subtracting the known percentage of the milk from the desired percentage of the mixture to obtain the amount of cream to be used.

Thus, in the above stated example, $40 - 16 = 24$ $16 - 4 = 12$. This can best be illustrated by drawing a square and placing the figures as shown in the accompanying diagram:



It will be noticed that in this particular example the proportions of cream to milk are 12 : 24; that, in other words, by mixing together 12 gallons of 40% cream and 24 gallons of 4% milk there will be obtained 36 gallons of 16% cream.

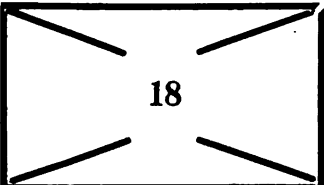
The correctness of this procedure may be thus proved. Cream testing 40%, 12 quarts or gallons; milk testing 4%, 24 quarts or gallons:

$$\begin{array}{rcl}
 .40 \times 12 & = & 4.80 \\
 .04 \times 24 & = & 0.96 \\
 \hline
 36) & 5.76 & (.16 \quad .16 \times 36 = 5.76 \\
 & 36 & \\
 \hline
 & 216 & \\
 & 216 & \\
 \hline
 & 0 &
 \end{array}$$

If one wishes to know for example how much cream should be added to a 40 quart (10 gallon) can of 4% milk to make a 16% cream, the ordinary rule of proportion is involved.

$$24 : 12 :: 40 : x = 20 \text{ qts. or } 5 \text{ gals.}^1$$

Example 2. Given a 42% cream to be reduced by skimmilk to an 18% cream. The square will be:

42		18 (18 - 0 = 18)
0		24 (42 - 18 = 24)

Mixing in the proportion of 18 cream and 24 skimmilk, the result is attained. Figuring as before for proof: $42 \times 18 = 7.56$ $.00 \times 24 = .00$ $7.56 + .00 = 7.56$ $18 + 24 = 42$ $7.56 \div 42 = .18$. If one wishes to know for example how much cream should be added to 10 gallons of skimmilk to make an 18% cream, one figures as before. $24 : 18 :: 10 : x$. $x = 7\frac{1}{2}$ gallons as may be proven thus:

.42	×	7.5	= 3.15	
.00	×	10	= 0.00	
17.5	)	3.15	(.18	
		175		.18 × 17½ = 3.15
		100		
		100		

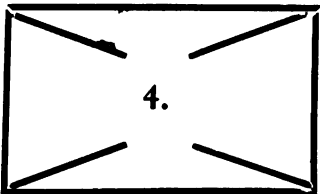
Or, reversing the proposition, if one has a 10 gallon can of 42% cream and wishes to know how much skimmilk to add to it to reduce it to an 18% grade, one figures $18 : 24 :: 10 : x$

¹Strictly speaking, and for work of extreme accuracy, cognizance should be taken of the *weights* of cream and skimmilk rather than of their volumes. But as a matter of fact this is quite unnecessary for ordinary commercial purposes. Any minor error introduced by the use of volume rather than of weight in calculation is far within the limit of error of the operations of sampling and testing. In view of this fact, and of the added consideration that calculation on the weight basis, while not intricate, is notwithstanding much less simple than is that on the volume basis, the latter system only is used for purposes of illustration.

$x = 13\frac{1}{2}$ gallons which will be found sufficient.. Proof:
 $.42 \times 10 = 4.2$. $.00 \times 13\frac{1}{2} = 00$ $4.2 + 00 = 4.2$ $10 + 13\frac{1}{2}$
 $= 23\frac{1}{2}$ $4.2 \div 23\frac{1}{2} = .18$.

Factories wishing to use whole milk for modifying purposes naturally wish a standard milk for this purpose. Hence the next example, which deals wholly with milk, is pertinent.

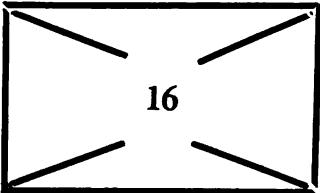
Example 3. Given milks carrying $3\frac{1}{2}$ and 5% fat to be mixed to make 4% milk:

5.		.5	$(4 - 3\frac{1}{2} = \frac{1}{2})$
3.5		1	$(5 - 4 = 1)$

$\frac{1}{2} : 1 :: 1 : 2$. Hence one can of the lower and two of the higher grade will make three cans of the 4% grade. Any other figures may be used as desired; as for example 4.6 and 3.3 to make a 3.7% grade. $4.6 - 3.7 = 0.9$ $3.7 - 3.3 = 0.4$. Four parts of the higher grade and nine parts of the lower are called for.

By means of the homogenizer (page 39) a cream fit for ice cream can be made from an unsalted butter, using whole or skimmilk as a fluid means to this end. Hence the next two examples have direct bearing upon this matter.

Example 4. It is desired to make a 16% cream from unsalted butter and skimmilk. It is fairly safe to assume that such butter carries 82% fat, but it is hardly safe to assume a higher amount. The figure then stands as below:

82		16	$(16 - 0 = 16)$
0		66	$(82 - 16 = 66)$

It will then require 16 pounds of unsalted butter for every 66 pounds or pints of skimmilk. This proves as follows:

$$\begin{array}{rcl}
 .82 \times 16 & = & 13.12 \\
 66 \times 66 & = & 0.00 \\
 \hline
 82 &) & 13.12 \quad (.16 \quad \text{fat; for } .16 \times 82 = 13.12 \\
 & & 82 \\
 \hline
 & & 492 \\
 & & 492
 \end{array}$$

In one problem which was considered in practical work, 34 pounds of butter were to be used and the operator needed to know how many pounds of skimmilk to put with this butter, which tested 82% fat, to produce a cream testing 16%. His proportion stood $16 : 66 :: 34 : x$. $34 \times 66 \div 16 = 140$. He needed 140 pounds of skimmilk to add to his 34 pounds of 82% unsalted butter to produce a 16% cream.

Reversing the problem: one has a can of skimmilk weighing 85 pounds; how many pounds of 82% unsalted butter are needed to make therewith a 16% cream? The proportion will read, $66 : 16 :: 85 : x$. $16 \times 85 \div 66 = 20.6$. 20.6 pounds of unsalted butter, if homogenized with one 40 quart can of skimmilk, will produce a 16% cream.

Another very convenient tool in this connection is a rule by means of which one may find directly how many gallons (or pounds) of rich cream and a skimmilk will be required to produce any definite number of gallons (or pounds) of a cream testing any definite percentage of fat. The rule is: Multiply the amount of cream desired by the test of the cream desired and divide this product by the test of the rich cream at hand. This will give the amount of the rich cream required for the mixture. The difference between the amount of cream desired and the amount of rich cream required will indicate the amount of skimmilk required to be mixed with the rich cream to produce the desired result.

For example, suppose one has on hand cream testing 40% fat and skimmilk and that he wishes to know how many gallons of each will be required to produce 6 "jugs" or 6 ten-gallon cans of cream testing 18% fat. The formula will then be:

Amount of cream desired (60 gals.) $\times$ test of cream desired (18%) divided by test of cream at hand (40%) = number of gallons of rich cream required (27 gals.) or

$$\frac{60 \times 18}{40} = 27$$

and $60 - 27 = 33$ or the number of gallons skimmilk required to be added to the 27 gallons of 40% cream in order to secure 60 gallons of 18% cream.

$$\text{Proof } 27 \text{ (gal.)} \times 40 \text{ (\%)} = 1080$$

$$\underline{33 \text{ (gal.)} \times 00 \text{ (\%)}} = \underline{000}$$

$$1080$$

$$60 \text{ (gal.)} \times 18 \text{ (\%)} = 1080$$

In order to facilitate the calculations of modification, the following tables have been prepared, indicating the proportions of skimmilk and of creams of varying qualities from 18% to 40% which should be used in the making of a cream modified to definite percentages varying from 10 to 25%. The first table is based on the use of 6 gallons of the fluid raw material, from which, if the process is properly conducted, 10 gallons of the completed and frozen goods may be obtained (see page 32). The second shows the proportions in terms of pounds or pints of the two materials used in making a definite grade of finished product. For home making purposes the error in assuming that a pint of cream will weigh a pound will not be important.

MODIFICATION TABLE FOR USE IN MAKING APPROXIMATELY
TEN GALLONS OF ICE CREAM

Showing the approximate amounts of cream and of skim-milk needed to obtain 6 gallons of cream before freezing. The figures are stated as GALLONS.

Quality desired.	10%	12%	15%	18%	20%	22%	25%
Kind of stock,							
18% cream,	3½	4	5	6			
Skim milk,	2½	2	1	0			
20% cream,	3	4	4½	5½	6		
Skim milk,	3	2	1½	½	0		
22% cream,	2¾	3½	4	5	5½	6	
Skim milk,	3½	2¾	2	1	½	0	
25% cream,	2¾	3	3¾	4½	4¾	5½	6
Skim milk,	3¾	3+	2¾	1¾	1¾	¾	0
30% cream,	2	2½—	3	3¾	4	4½	5
Skim milk,	4	3½+	3	2¾	2	1¾	1
35% cream,	2—	2+	2¾	3+	3⅞	3¾	4⅞
Skim milk,	4+	4—	3½	3—	2⅞	2¾	1⅞
40% cream,	1½	1¾	2¼	2¾	3	3⅞	3¾
Skim milk,	4½	4¾	3¾	3¾	3	2⅞	2¼

NOTE.—This table may be used as follows: An 18% cream is to be frozen. One has a 30% cream on hand and skim milk. One follows the perpendicular column headed 18% downwards until the location is reached which is on the horizontal line bearing the title at the left "30% cream." The figures at this point show the proportions of 30% cream (3¾ gallons) and of skim milk (2¾ gallons) needed to make an 18% cream.

MODIFICATION TABLE FOR USE IN MAKING APPROXIMATELY
A GALLON OF ICE CREAM

Showing the approximate amounts of cream and skimmilk needed to obtain 4 pounds of fluid cream before freezing of the desired grades. The figures are stated as POUNDS or PINTS.

Quality desired.	12%	15%	18%	20%	22%	25%
Material on hand						
to be mixed						
18% cream,	2.7	3.3	4.			
Skimmilk,	1.3	.7	.0			
20% cream,	2.4	3.	3.6	4.		
Skimmilk,	1.6	1.	.4	.0		
22% cream,	2.2	2.7	3.3	3.6	4.	
Skimmilk,	1.8	1.3	.7	.4	.0	
25% cream,	1.9	2.4	2.9	3.2	3.5	4.
Skimmilk,	2.1	1.6	1.1	.8	.5	.0
30% cream,	1.6	2.	2.4	2.7	2.9	3.3
Skimmilk,	2.4	2.	1.6	1.3	1.1	.7
35% cream,	1.4	1.7	2.1	2.3	2.5	2.8
Skimmilk,	2.6	2.3	1.9	1.7	1.5	1.2
40% cream,	1.2	1.5	1.8	2.	2.2	2.5
Skimmilk,	2.8	2.5	2.2	2.	1.8	1.5
45% cream,	1.1	1.3	1.6	1.8	2.	2.2
Skimmilk,	2.9	2.7	2.4	2.2	2.	1.8
50% cream,	1.	1.2	1.4	1.6	1.8	2.
Skimmilk,	3.	2.8	2.6	2.4	2.2	2.

NOTE.—This table may be used as follows: A 20% cream is to be frozen. One has a 35% cream on hand as well as skimmilk (whole milk may be used instead and the ice cream be none the worse and probably a good deal the better for it, if it is not made over-rich). One follows the perpendicular column headed 20% downwards until the point is reached which is on the horizontal line bearing the title at the left "35% cream." The figures at this point show the weights (lbs.) or measures (pints) of 35% cream (2.3) and skimmilk (1.7) needed to make 2 quarts or 4 pounds of a 20% cream.

TESTING ICE CREAM FOR FAT

The testing of ice cream for butter fat in a manner applicable to the purposes of the factory is considerably more difficult than is the testing of ordinary milk or cream, because of the presence of the large amount of cane sugar. There are two or more methods for making such fat tests, which, though doubtless of value in chemical laboratories, are too complicated and tedious to be of the highest value in the factory where rapidity of work is a prime essential and where only approximately accurate results are required.

The following method has been used by the writer with excellent results, the fat column being as clear and clean as are those attained in ordinary work with milk or cream. This method, or rather modification of an existing method, although requiring care and close attention to details in order to achieve satisfactory results, is not essentially difficult.

Carefully weigh 18 grams of a well melted (but not overheated) and mixed sample of ice cream into a .30% cream bottle. To this, add 4 or 5 c.c. of lukewarm water. Now add ordinary sulphuric acid, a little at a time, thoroughly mixing the fluids with each addition. Little more than half and seldom as much as two-thirds the usual amount of acid is required; and not more than one-half of this amount should be used at the outset, and some little time should be allowed for it to act. If the color is not yet that of strong coffee, add a little more acid, shake and pause for a time. If still the color is too light, add yet more acid. In this way the color is built up to the desired point. When the contents of the bottle have assumed almost the desired amber color, add 4 or 5 c.c. of cool water to check the further action of the acid. The test is thereafter conducted as would be an ordinary cream test, care being taken that the machine does not become too hot during whirling. If this scheme is carefully followed, particularly in the matter of the slow and gradual addition of the acid, the fat should appear in the neck of the test bottle of a clear, light brown color and distinct from

the solution below. When this distinct, clean-cut condition has been obtained, the tester may feel sure, provided the work has been in other respects carried out in accord with the well understood details of the Babcock method, that the results will be reasonably accurate.

SCORE CARD

Perhaps no two people working separately would devise one and the same score card for ice cream, or for any other product for that matter. Score cards are used now in the judging of butter, cheese, market milk, domestic animals, farms, farm buildings, etc. They are quite generally compromises, representing the modified opinions of several men. Moreover, score cards are revised from time to time as experience indicates the need of modification. It is more than probable, therefore, that the following score card, the first so far as the writer knows which has been issued, will need to be revised, when ice cream becomes a standard article for scoring at dairy conventions, as is now the case with butter, cheese, market milk and cream.

Flavor	45
Body	20
Texture	20
Permanency	10
Package	5

100

Flavor. To be that of clean, sweet cream sweetened to taste with cane sugar; the score to be cut for any flavor of sour cream, and cut severely for any dirty flavor, and but little if too sweet or not sweet enough, or if the added flavor is too high or too low, for these are largely regulated by trade demands.

Body. To be firm, mellow and slightly elastic under pressure of the finger at a temperature of 18° F. or less. It must not be rubbery or too weak.

Texture. To be smooth, creamy and free from coarse water crystals; the score to be cut moderately if too coarse, and severely if inclined to be sticky or doughy.

Permanency. To have a reasonable standing-up power on an ordinarily cool dish, and to offer some resistance in the mouth, instead of melting and disappearing as liquid almost immediately upon being tasted.

Package. To be clean, tidy and free from evidences of slovenly workmanship.

CALCULATION OF YIELDS

The only proper basis upon which to calculate the yield and swell is that of the weight of the entire mixture. To say that so many gallons of cream have been worked up into so many more gallons of ice cream, without taking into account how much skimmilk, sugar, etc., may have been added to aid in that increase, is confusing and does not conduce to accurate work. The ice cream maker should not be content with less than 50% swell (page 32). When the goods are made in a batch freezer of the old type, the swell may be approximately determined by comparing the depth in inches of the finished article with that of the mix placed in the can (measured either with or without the dash in both cases). For example, if 5 gallons of cream and $7\frac{1}{2}$ pounds of sugar in a 10 gallon freezer can measure 14 inches in depth, and if the batch when frozen measures 23 inches in depth, the difference or swell is 9 inches. This difference in depth, 9, divided by the original depth, 14, gives us the percent of swell, i. e., 64%. This method of measurement, however, is rather crude and is not applicable to the continuous freezers, to those batch machines which work horizontally, or to those batch freezers which, though vertical, draw the finished ice cream from the bottom without stopping the machine. It is much better to work by weight. The difference between the weight of a can full of the "mix" unfrozen, and the weight of the same can full of the finished ice cream is caused by the air the latter contains. Suppose, for instance, the ice cream is regularly set away for holding in 25 quart cans. It will be found that these, when filled with mix, weigh about 64 pounds, the can

weighing 11 pounds and the 25 quarts of mix, 53 pounds. Now if this can is filled with ice cream as it is taken from the freezer, its gross weight will be, say 50 pounds, and its net weight 39 pounds. Now obviously the 39 pounds weight is due to the cream, milk and sugar and not to the air. Then these 39 pounds are 39 of the 53 pounds which filled this can prior to the freezing. The can is full of the finished, expanded, swelled product, and there are 14 pounds surplus or over-run not in the can. This 14 pounds represents in terms of weight the "swell"; and it is easy to calculate it in terms of percentage, $39 : 14 :: 100 : x = 36\%$. A 25 quart can holds $6\frac{1}{4}$ gallons, and a gallon of the finished article weighs then $6\frac{1}{4}$ pounds, ($39 \div 6\frac{1}{4} = 6\frac{1}{4}$). This is too heavy a weight and too small a swell. A maker should not rest content with such results. If, by better understanding of the principles and practice of his trade, he incorporates enough air to reduce the net weight of a can full of finished ice cream to 33 pounds instead of 39 pounds, the surplus will be 20 pounds and the swell will calculate $33 : 20 :: 100 : x = 60\%$; and a gallon will weigh $5\frac{1}{4}$ pounds ($33 \div 6\frac{1}{4} = 5\frac{1}{4}$). Here is a difference of a pound per gallon. If the cream-sugar-gelatin mixture costs say 7 cents a pound, there will be a saving of 7 cents in the cost of each gallon of ice cream. If, then, 100 gallons of ice cream are made daily, the monetary advantage of a 60% swell over a 35% swell amounts to \$7 daily, on the initial cost of the raw material, not to speak of the larger volume of the sales product and the increased gross income thus obtained. A full gallon of mix made from an 18% cream weighs before freezing $8\frac{3}{4}$ pounds. A gallon of the frozen ice cream ought not to weigh less than 5 pounds, which represents a 75% swell, or more than 6 pounds, which represents an increase of about 45%.

The following table illustrates approximately the results obtained by getting this or that percent of swell, when a $6\frac{1}{4}$ gallon can of mix weighs 53 pounds net:

Gross weight, pounds	Net weight, pounds	Swell, percent	Weight of one gallon of ice cream, pounds
41	30	77	4.81
42	31	71	4.97
43	32	66	5.13
44	33	61	5.29
45	34	56	5.45
46	35	51	5.61
47	36	47	5.77
48	37	43	5.93
49	38	39	6.09
50	39	36	6.25
51	40	33	6.41

COST OF EQUIPMENT

The cost of equipping an ordinary creamery with ice cream making machinery and tools will depend very largely upon the scale upon which the business is to be done. Assuming abundant water, steam and power facilities, ample floor space and ice, which are usually the conditions at village creameries, the matter of equipment will be limited in the main to a freezer, which will cost \$75 and up; an ice crusher, if one be procured, \$75 and up; or a combined freezer and ice crusher, \$100 and up; cans for holding, \$25 and up; holding tank, \$25 and up; smaller tools and conveniences, \$25 and up. The probable minimum cost of starting in such business would doubtless be about \$225 to \$250. This figure may be much increased if the larger or more expensive machines are purchased, or if the business is entered upon in a caterer's style; which step, however, is not recommended.

There are several types and many makes of freezers on the market. Each doubtless has its points of superiority over others. The old style upright 40 quart freezer will doubtless be found economical and serviceable under most Vermont creamery conditions. There are many firms dealing in ice cream machinery and supplies, who will gladly assist creamery men in making selections of machines and material. The writer refers the prospective ice cream maker to such catalogs and firms for exact figures.

PROFITS OF THE INDUSTRY

The profits derived from any business naturally depend largely upon the technical skill and business ability of the men engaged in it; and also to a yet more controlling degree upon market conditions. Not every Vermont creamery should attempt ice cream making even as a side line. The lack of a market would preclude success in many cases. There are many creameries, however, which would doubtless find it profitable to engage in the manufacture of simple creams during the summer season, while the milk and cream supply is greatest and the price of butter fat is least.

Assume 100 pounds of cream testing 18% butter fat. This should make a little more than 21 pounds of finished butter, which, if sold at 28 cents a pound, will bring \$5.90. If, however, this same 100 pounds or 12½ gallons of cream is made into ice cream, it should, through the addition of sugar, and because of the swell, easily produce 20 gallons of finished ice cream. If this sells at 80 cents a gallon, a fair wholesale price, the product brings \$16. About a dollar's worth of sugar will be used in 12½ gallons of cream. In the one case the 18 pounds of butter fat is sold for \$15, in the other at less than \$6; at about 83 cents per pound when sold in ice cream, as against about 33 cents per pound when sold as butter. Many minor outlays, for flavoring extract, salt, ice, etc., serve to lower the net profit to some extent; but even then it is ample. Where a good sized village is close at hand, or where good shipping facilities to nearby villages are sufficient, the creamery management may well consider the advisability of establishing ice cream making as a side line to the butter-making industry. However, if it concludes to embark in this enterprise, it should not attempt to make fancy creams, which, while profitable, present special problems, but to do thorough work on the plain varieties which are simpler and more commonly demanded.

PROBLEMS FOR FURTHER STUDY

Although it is thought that this bulletin has thrown some light upon processes not previously understood, there yet remain several knotty problems to be solved.

Bacterial changes in stored ice cream is a subject which merits thorough study by the chemist and the bacteriologist. How long may ice cream be held in storage with safety? Under what conditions? What changes take place? How rapidly? Especially, is it fact or fancy that ptomain poisoning is caused by the consumption of old ice cream? Just what are the conditions of manufacture, storage, etc., which favor ptomain development? Is ice cream a factor in the transmission of contagious disease, as are milk and cream? These and other problems vitally affecting public health demand solution.

Economical refrigeration. This is a problem for refrigerating engineers. That there is at present an extreme waste of energy is very apparent. The requirements for the freezing and the refrigerating of ice cream are peculiar to the industry and need considerable further study, both in connection with artificial refrigeration and in connection with the use of the everyday ice and salt as refrigerating agents.

Plan of ice cream factory. The writer has been impressed, in his study of this subject, with the immense number of unproductive steps taken and the wasteful amount of lifting done in the average ice cream plant. Thorough public discussions of the best arrangement of machinery, cooler, etc., for butter and cheese factories and market milk plants have resulted in almost ideal arrangements for these plants, where the maximum of work may be done with the minimum of human effort. This matter has undoubtedly been studied by many capable men and it would certainly be a benefit to most of the manufacturers of ice cream, as well as to the public, if these plans could be assembled, worked over, revised and published by some one competent to discuss the subject.

X. REFERENCES AND BIBLIOGRAPHY

Before beginning to make ice cream in a commercial way the would-be maker should procure one or more books, giving recipes of different kinds and qualities. True, these may be found in almost any cook book; but most of them are for small batches and they are often clumsily stated. Val Miller: "Standard Recipes for Ice Cream Makers," published by Laird and Lee, Chicago, Ill.; and an anonymous book, "Ice Cream and Cakes," published by Chas. Scribner's Sons, New York, seem fairly authoritative books in their lines. They deal almost entirely with the mixtures and their compounding and with handy contrivances. They have nothing to say as to the principles of freezing and but little of method. The novice in ice cream making will doubtless find the "Ice Cream Trade Journal," published by the Cutler-Williams Company, 150 Nassau St., New York, of especial interest for current news items and experiences. The New York Produce Review, No. 173 Chambers St., New York, occasionally has an ice cream discussion page, which contains some excellent matter, and the Dairy Record, St. Paul, Minn., has printed some good ice cream articles by Prof. C. Larsen.

Much the cheapest way to gain experience is, so far as possible, to buy it; to get ideas from those who have gone before, thus clearing the road for actual advance during the future. Therefore, he who would embark upon such an enterprise should read and think in order that power of observation may be quickened and experience made to be of yet more value.

There are almost no articles treating on ice cream making save from the standpoint of the caterer. Such few as the writer has found are listed below.

Penny. Dela. Sta. Rpt. 5, pp. 123-124 (1892).

Van Norman. Cyc. Am. Agr. (Bailey) III, pp. 195-198 (1908).

Melick. Md. Sta. Bul. 136 "Whipped Cream" (1909).

Wiley. Marine Hosp. Serv. Bul. 41, pp. 245-305 (1908).

Reports of sundry state food and dairy commissioners (analyses of commercial creams),

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UNIVERSITY OF VERMONT
AND STATE AGRICULTURAL COLLEGE

VERMONT AGRICULTURAL
EXPERIMENT STATION

BURLINGTON, VT.

BULLETIN NO. 156

JANUARY, 1911

**The Management of Vermont Forests with
special reference to White Pine.**

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BULLETIN 156: THE MANAGEMENT OF VERMONT FORESTS WITH SPECIAL REFERENCE TO WHITE PINE

FOREST SERVICE PUBLICATION NO. 4

A. F. HAWES, State Forester

PART I

THE MANAGEMENT OF FORESTS

The value of a forest depends upon a number of factors: the kinds of trees present; their condition and health; the number of trees per acre; their diameters and heights; their taper; the accessibility of the tract for lumbering; and its distance from a market or railroad.

In Vermont there are no forests as valuable as those composed of white pine, and the less mixture of other trees there is, the more valuable they are. No perfect forest can have large openings and it is just as important not to have too many trees as to have too few. The size of the trees, i. e., their diameters, heights and taper, depends largely on the amount of crowding; hence the forester's attention is largely directed to this question.

THINNING AND CUTTING

The forester distinguishes two kinds of cuttings and it is very important that they be kept entirely distinct in the mind of the woodland owner. First in the life of a forest is the improvement thinning, which removes a certain portion of the standing trees in a young wood for the purpose of improving the main crop which is left. The trees so taken out may or may not yield a profit, according to their size and the condition of the market. The purpose here is to improve the quality and quantity of the main crop which is not to be cut until later. Entirely distinct from such a thinning is the final cutting the forester makes in a mature wood. Here profit is the prime object and not the improvement of the trees which are left, although the appearance of such a cutting by a forester often resembles more a thinning

than it does the logging operation of a lumberman. Such an operation is called the "final cutting."

The purpose of this bulletin is to describe the kind of thinnings and final cuttings applicable to the forests of Vermont, and especially to pine forests.

TREE GROWTH¹

Trees, like other plants, are dependent upon the soil for the several mineral forms of plant food, more especially potash, lime, iron, and phosphoric acid. The nitrogen also is soil derived, though non-mineral in its nature. The root systems of trees are so diversified that these plant foods are almost always obtainable in any forest soil, but they can only be taken up in the form of very weak solutions. An adequate moisture content of the soil is, therefore, more apt to be lacking, thus unfavorably influencing the growth of the trees, than is the quantity of mineral forms of plant food likely to be deficient. Most of the water imbibed is transpired through the foliage, but a certain portion is used for the formation of tissue. Different species of trees make various demands upon the soil for moisture, moreover the demand on the part of the same species varies with soil, climate, exposure, etc. The finer the soil and the greater the proportion of humus, the more moisture will the soil hold. For all kinds of woodland crops there is on the one hand a minimum supply of water requisite for thrifty and healthy development, and on the other hand a maximum beyond which any surplus of moisture is prejudicial to tree growth. While some trees, as the pine, can thrive on drier and sandier soils than can others, such as the maple and beech, they all do better on a moist loam, or soil with some admixture of clay. The best indication of the quality of a soil for tree growth, both as to its mineral and its water contents, is afforded by the height growth of the tree. Thus, for example, a study of the white pine in Pennsylvania

¹This portion of the bulletin appeared in a paper by the writer delivered before the Vermont State Horticultural Society.

showed the average height growth in 50 years on diverse grades of soil to be respectively, 64, 46 and 30 feet. Now a 64 foot tree will also be larger in diameter and will require more growing space than a shorter tree. Hence there are fewer trees per acre on a good soil than there are trees of the same age on a poor one. The number of trees per acre on these three quality sites at 50 years were respectively 379, 495 and 686 from the best to the poorest. While the number of trees per acre was smaller on the better soils, they were so much larger in size that the total crop per acre in board feet on the best soil quite outclassed that on either of the poorer soils.

Light is as essential to tree growth as are water and plant food. By the action of light on the chlorophyll contained in the leaves, the tissues of the tree are in a large measure formed. The amount of light needed by different kinds of trees for their constructive work varies considerably and can be judged to some extent by the foliage. Thus a tamarack with its delicate light foliage requires a great deal more light than does a maple with a large and densely leafy crown.

The two essentials, then, which regulate the development of a forest are soil moisture and light or space. So long as a healthy tree has plenty of both it should grow well. If the water supply is seriously diminished or cut off by lowering the water level in the soil, the trees become stag headed and die. This is why many trees die about new houses where the water level has been changed. If they become so crowded that they only get light from above, the lower limbs die out, they become spindling and gradually die. (See plates 2 and 3 opposite page 112).

The tree that grows out in an open pasture has an unlimited supply of both moisture and light. The lower limbs have the same opportunity for light that the top has and therefore the tree develops a very branchy character, much of its food going into the production of limbs instead of a tall trunk. All these limbs are producing a wood material which must be deposited in the limb or lower down on the trunk. So the base of

the tree becomes larger and larger as its branches grow, and the log when cut will not only be very knotty but so tapering that only narrow boards can be cut at the top.

The development of a tree in a forest is quite different from that of one located in the open. Imagine, for example, a plantation in which the trees are six feet apart. In about six years the lower limbs of these trees come together and soon begin to crowd each other. By fifteen years many of these lower limbs will be killed out. Gradually they drop off, leaving a smooth trunk. As the tree can only gain light from above, every effort is put into height growth and the main height growth is made during the first part of a tree's life, as is shown in the following table for chestnut trees grown from seed:

TABLE I. HEIGHT GROWTH OF CHESTNUT

Age in years	Height in feet	Growth each ten years in feet
10	7	7
20	17	10
30	33	16
40	52	19
50	64	12
60	73	9
70	80	7
80	84	4

The growing part of a tree located in a forest is always the top. The food that is made is not wasted as in the pasture grown tree in the production of large limbs, but is deposited in the crown, so the log produced is not only free from limbs but is well filled out at the top (plate 3). Boards cut from such trees will be free from large knots and will be nearly as wide at the top as the bottom.

During the struggle for existence not only are the lower limbs killed out, but many trees become suppressed by their more successful competitors. Left to nature's ways the struggle may become so intense that almost all the trees will be weakened. Their side branches may be killed too far up into the crowns so that they become spindling and their tops produce very little wood.

A study of natural groves of white pine in New England illustrates the severity of this contest as shown by the following table:

TABLE II. NUMBER OF TREES PER ACRE AT DIFFERENT AGES

Age in years	Average height in feet	Number of trees per acre	Number of trees dying per decade
10	5	2220	...
20	14	1600	620
30	32	1090	510
40	54	690	400
50	68	400	290
60	76	260	140

IMPROVEMENT THINNINGS

In our forest management we must consider whether it pays to allow this struggle to go on uninterrupted. It is not enough to go through the forests and remove the dead trees. While this may improve the appearance of the forest and may in some cases produce a small income, it does not affect the growth of the remaining trees. In order to produce the best results one must keep a little ahead of nature's method by allowing each tree that is to remain ample room for the development of its crown. The best trees should always be left and only those trees cut which will interfere with their development. This thinning should not be made until the trees are about twenty years old. It is better to make repeated light thinnings, say every six or eight years, than to make heavy thinnings which will expose the trees to the effect of wind and ice storms. No openings should be made, since such encourage the growth of grass and weeds and the drying out of the soil. In selecting the trees to be left one should choose such as possess well developed crowns. Usually in the case of spruce and pine the crown should occupy at least one-third of the total height. The development of wood material by a crown which does not occupy more than one-fifth of the total height is inadequate.

Another point to be borne in mind is that a thinning made just before a seed year of any species results in a great increase in the amount of seed produced, and that the reproduction of that species on adjoining areas or openings may be affected thereby.

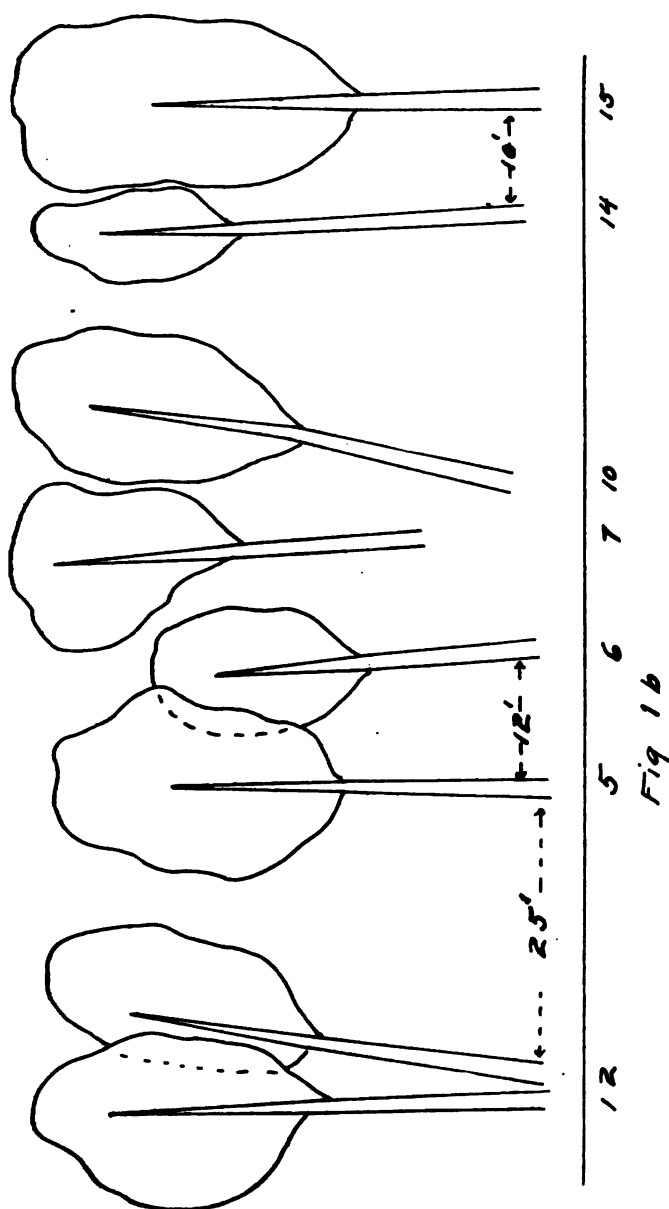


FIG. 1. b. This represents the same group as 1. a. ten years after the thinning described above. Note how the crowns have filled out, enabling the trees to make a good height and diameter growth. These trees stand from 10 to 25 feet apart, but most of their crowns touch each other.

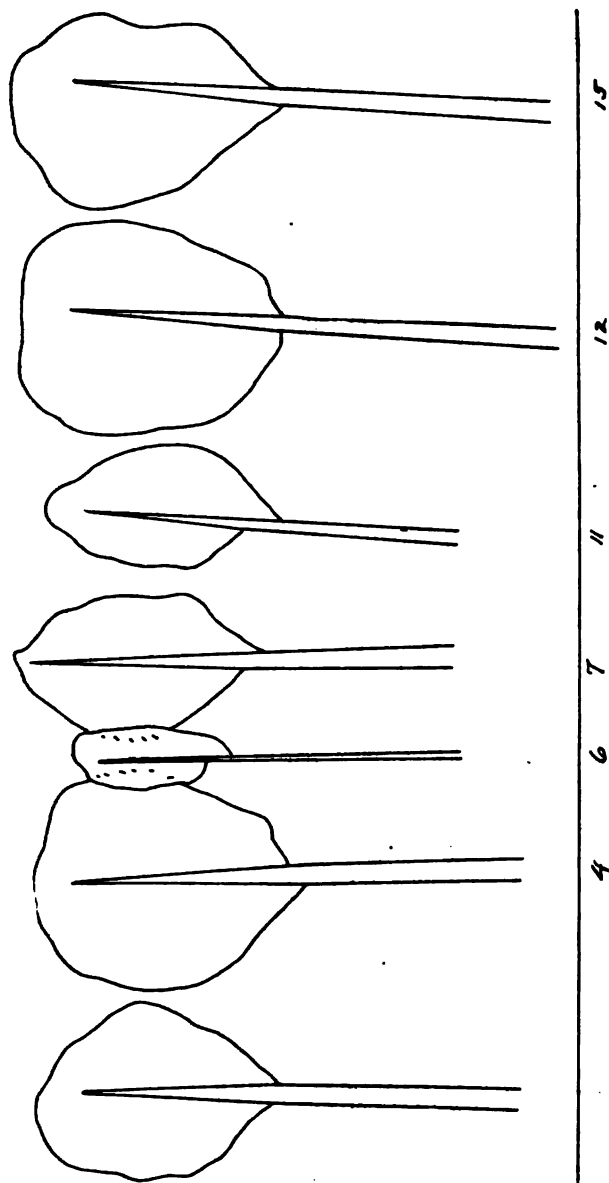


Fig. 2 b.

FIG. 2. b. This represents the same group as 2. a. ten years after the thinning described above. The tops have now come together and the forest would need another thinning. 6 still has a small top and is splindling and it is a question if it would not have been better to have removed it at first.

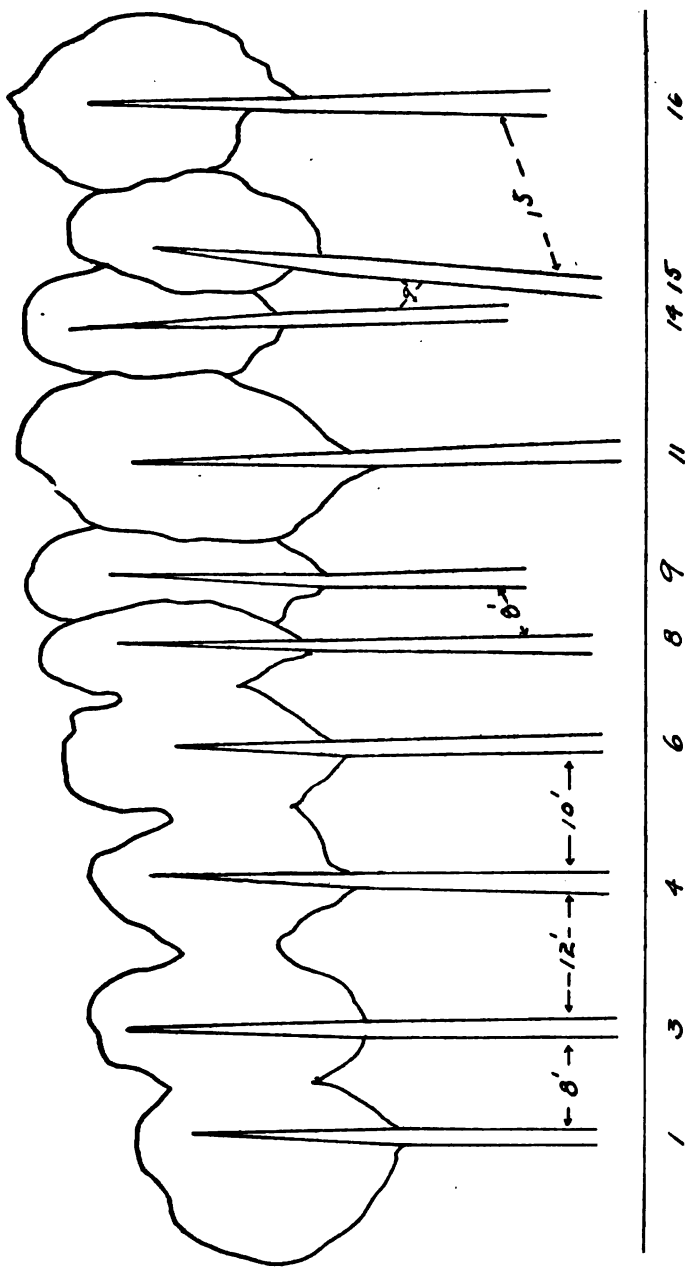


Fig. 3 b.

Fig. 3b. This represents the same group as 3a ten years after the thinning described above. The crowns have now grown together and another thinning is needed.

The selection of the trees to be removed is based upon species and condition. As a rule in Vermont the trees to be most favored are: White and red pine, spruce, sugar maple, white ash, basswood, yellow birch, and wherever they occur, hickory, red oak and chestnut. Those which might be sacrificed to benefit thrifty specimens of the above are: hemlock, fir, pitch pine, butternut, beech, poplar, elm. A few worthless species, such as the ironwood and bird cherry, should always be cut so as to prevent their seeding.

No hard and fast rule can be laid down for thinning. It will not do, for example, to say that every other tree should be cut, or that in clumps of five sprouts, one or any definite number should be cut. Neither can one say that a pitch pine should always be cut when crowding a white pine or a beech when crowding an ash. If the pitch pine is straight and the white pine crooked, one should reverse the rule, and if the beech is sound and the ash unsound, of course the ash should be cut.

As to the number of trees or the amount of wood which should be thinned out, it is only necessary to repeat that frequent light thinnings are better than are long deferred heavy thinnings. As the trees removed in thinnings are always of the smaller sizes, the number of trees taken out is a greater proportion of the total number in the woodlot than is the volume removed of the total volume. As a rule from one-fifth to one-quarter of the volume of the standing wood is cut; so on a tract bearing 30 cords to the acre from 6 to 8 cords would usually be taken.

REMOVAL OF UNDERBRUSH

Many people have the impression that the removal of underbrush is a desirable measure. From a forestry standpoint this practice cannot be recommended. The material removed has no value to compensate for the operation, which is quite expensive. A new undergrowth usually sprouts readily and grows up more luxuriantly than ever. Underbrush is more of a benefit than an injury to the forest, since it shades the ground, prevents evapora-

tion and adds to the humus by its decaying leaves and twigs. In some cases it interferes with the growth of seedlings. If a forest is of proper density there will be little underbrush. A few shrubs, such as laurel and rhododendrons, are exceptions, and while they are very beautiful, they are a serious enemy to the forest, because of their thicket forming propensities.

PRUNING

No attempt is made here to consider pruning in its relation to shade, ornamental or fruit trees. From a forestry standpoint pruning is a very questionable operation. Its need is always an indication that forestry operations have been poorly conducted in the past, for, as has been shown, trees grown closely together will prune themselves.

In parts of Vermont the spruces which come up on old pastures are known as "bull spruces" and by many are considered a different kind of tree from the spruce of the forest. The only difference they exhibit as compared with forest grown type is that when grown in the pasture they have the limby character and are better fitted for Christmas trees than for timber. As they grow up there will be many thickets where natural pruning takes place. Others out in the open will always be limby unless these limbs are pruned off. Pruning these larger limbs causes much "bleeding" of the tree, entails the loss of the food material which the limbs would produce, and results in the formation of loose knots, which are worse defects in lumber than are the knots of live limbs. Such trees should never be pruned.

In dense stands of pine, spruce, cedar and other conifers the dead limbs often persist on the trunks, making it difficult to walk through the woods. The quality of such lumber will be bettered if the dead limbs are knocked off with a club. When not too expensive it is advisable to prune off any small live limbs close to the trunk with a sharp ax, so that the wounds will readily heal over. No live limbs of more than an inch in diameter should be pruned from conifers. With hardwoods the question is simply

whether the trees will be enough benefited to repay the expenditure. Except to form the shape of young trees by the removal of one leader or some of the lower branches, pruning cannot even here be considered a profitable operation.

FINAL CUTTINGS

As stated above the final cutting is made when the timber is mature or has reached its most profitable size. It is made solely for profit, just as is the lumberman's cutting. The distinctive difference between this cutting and lumbering, however, consists in this: that the lumberman usually cares only for the crop, takes no thought of the morrow and expects to abandon the land to its fate and, therefore, plans to get all he can at one time from it, while the forester, on the other hand, expects to raise another forest and, therefore, cuts with a view to a second growth. This young growth may be either artificial, in which case the forest is cut clean and planted; or it may be natural, secured by some provision such as is described later below.

CLEAN CUTTING WITH PLANTING SYSTEM

In the first part of its application this method does not differ materially from old time lumbering except that the tops of the felled trees are usually burned to make room for the young seedlings that are to be planted. The subsequent planting need not be discussed here, except to say that transplants will be necessary to compete with the brush and that every provision should be made against fire before going to this expense.

NATURAL REPRODUCTION OF FORESTS¹

Inasmuch as planting is an expensive process and necessitates an investment of a considerable sum of money for a long term of years, and in view of the fact that the soil exposed by extensive clear cutting is apt to dry out and deteriorate, several methods have been developed for removing the final crop in such a way as to secure a seeding of desirable species. In some of these

¹See Vt. Sta. Circ. 6; Forest Publication No. 5, (1911).



PLATE I

Natural application of Strip System of reproduction in pine, owned by the University of Vermont at Burlington. The forest on the left is 60 to 70 years old, and from it the one on the right 30 to 40 years old has seeded.



PLATE II

Typical pasture-grown White Pine 50 feet high; diameter 20 inches. Contents about 300 board feet. Note that large limbs persist to the ground making inferior knotty and tapering lumber.



PLATE III

Typical forest-grown White Pine, Richmond, Vt. Height 80 to 90 feet, contents 800 to 1,000 board feet. Note that the crown occupies over one-third of the total height, which insures the best growth.



PLATE IV

Stand of Second Growth White Pine 60 to 70 years old belonging to the University of Vermont. About 55,000 board feet to the acre. See p. 125.

methods the final cuttings are distributed over a long term of years, in others there is only a short term between them; but never is the whole forest cut at once, since good reproduction is impossible to secure in that way.

Selection system.—The popular conception of forestry is based upon this simple system, the principle of which is to remove trees here and there throughout the forest as they become mature.

Lumbermen fix upon a certain diameter, say eight inches on the stump, cut no trees under this diameter and call it forestry. This, however, is not the selection system rightly applied, for the cutting should be based more on the condition of the trees than on their size. Some small inferior trees should be cut and some large seed trees left. Seldom over one-third of the standing timber is removed at a cutting under this system. Each year a portion of the forest is cut over in this way, so that at the end of, perhaps, a decade the mature timber of the whole forest has been cut, and the operations can be repeated at once if not made too heavily at first; or after a period of twenty years, if one-third of the timber was removed. The distinctive difference between this system and a thinning described above is that a thinning removes the smaller trees in a young forest, while the selection system removes the larger trees in a mature forest.

The stand system.—Managed in accordance with the stand system the forest presents much the same appearance to a lay mind as when handled according to the selection system. The object of this method is to gradually bring about an even aged forest in place of one in which trees of all ages appear as in the virgin forest. As the forest approaches maturity, provision is made for reproduction by a preparatory cutting. Any species not desired in the next generation are removed. This procedure opens up the soil to more light, which tends to favor the decomposition of the humus and thus to form a good seed bed; and it so opens up the crowns of the remaining trees that they bear a heavier crop of seed. Naturally the large spreading topped trees

are the ones left for seed production. After the ground has become well stocked with seedlings a reproduction cutting may be made, giving this young growth still more light; and a few years later the final cutting removes all the old trees, leaving the ground covered with an even aged stand of seedlings. These three cuttings made within a period of twenty years correspond to the one cutting under the clear cutting system and to the succession of cuttings made in accordance with the selection system every so often throughout the life of the forest. By both these last methods the reproduction is secured under the protection of the mother trees.

The characteristic of the group and strip systems is that the young seedlings start in the open.

Group system.—In every forest there are openings caused by wind, snow, insects or man. Many of these openings are covered with a young growth of seedlings such as fir or pine that are prospering in the sunlight. The opening has seeded in from the surrounding trees. Now if this opening is enlarged by removing a few of these surrounding trees there will be a narrow, open circle around the reproduction which will in time be similarly seeded in. This operation repeated every few years making the openings steadily larger, and going on simultaneously in various parts of the forest constitutes the group system. The final result is, of course, scattered groups of tall trees surrounded by circles of smaller trees growing successively smaller down to the seedlings starting on the outside. These circles in a bird's-eye view have the appearance of a rough target. The mature timber is removed in various parts of the forest at intervals of five or eight years, allowing for seed seasons, during a period of, perhaps, thirty years.

Strip system.—It will be seen that the group system is simply a form of clear cutting in small areas. The strip system is similar to it in this respect, except that the openings take the form of straight strips about one hundred feet wide, which areas

are to be seeded up from the forest to the windward. When well covered with young growth another strip is cut adjoining the first and this is seeded in the same way. If the prevailing wind is west, the first strip is cut north and south on the east side of the forest. The final forest thus secured presents the appearance of a set of stairs, the first strip being the tallest and the others grading down to the last which has to be planted. The mature timber is thus removed in a succession of cuttings as by the group system, but here the cuttings are regular and the roads may be straight.

Only a few of the systems outlined above can be applied in our Vermont rough timber land in the exact way in which they have been formulated, as a result of idealistic operations in foreign forests, but the ideas on which they are based can be applied to Vermont conditions. The remainder of this bulletin aims to show how they may be applied in pine forests. It will be realized that there is no marked difference in appearance between an improvement thinning in a middle aged forest and a selection cutting or preparatory cutting; but the method of making them and results attained are quite different.

PART II

WHITE PINE TABLES

There are various kinds of tables of use in forestry and lumbering, some of general application and others made to apply for one species only.

Log rule.—A "Log Rule" or "Log Scale" is a table of general application. There are a great many log rules in use in various parts of the country.¹ These rules purport to give the volume in board feet of logs of various diameters and lengths. They are made in various ways, a discussion of which is not necessary in this bulletin. The statutes of Vermont make the "Vermont rule" the legal scale. This rule is based on the premise that the

¹See Vt. Sta. Bul. 102 (1903) and U. S. Dept. Agr., Forest Service Bul. 36 (1909).

board foot contents of a 12 foot log are equal to the product of the small diameter by half of itself.

$$V = D \times \frac{D}{2}; \text{ where}$$

V = volume in board feet

D = diameter at the small end.

For shorter logs the volumes are proportional to the length.

For example, the volume by the Vermont rule of an 8-foot

$$\text{log, 16 inches at the top} = (16 \times 8) \times \frac{8}{12} \times \frac{2}{3} \times 128 = 85 \text{ board feet.}$$

Volume table.—A volume table, instead of giving the volume of felled logs, gives the volume of standing trees of different diameters and heights; and is a special table made for only one species. It is constructed by averaging together the volumes of a great many felled trees; and may be stated either in board feet, cords, ties, or any other denomination. After calipering the diameters of the trees on a lot and ascertaining their average heights, it is a simple matter to compute with this table the volume in board feet of each tree. It should be remembered, however, that its application is accurate for a number of trees rather than for an individual tree.

Tables III, V, VI and VII are taken from a pamphlet published by the State Forester of Massachusetts, written by Cook, entitled "Forest Mensuration of White Pine."

TABLE III. VOLUME TABLE IN BOARD FEET, FOR WHITE PINE IN MASSACHUSETTS

Scaled by rule made from mill tallies. Volume to 4-inch top. Stumps taken at $\frac{1}{2}$ foot

Diameter, breasthigh	Total height in feet						
	30 feet	40 feet	50 feet	60 feet	70 feet	80 feet	90 feet
	Board feet						
5 inches,	10						
6 inches,	15	20	30				
7 inches,	20	30	40	50	65		
8 inches,	25	35	50	65	85		
9 inches,	30	45	60	80	105	115	
10 inches,		55	75	95	125	145	
11 inches,		65	90	115	145	170	200
12 inches,		75	105	135	165	200	230
13 inches,		90	120	155	190	235	260
14 inches,			135	175	215	265	300
15 inches,			155	195	245	300	340
16 inches,			175	215	270	335	380
17 inches,				240	300	370	420
18 inches,				260	325	405	465
19 inches,				280	355	445	510
20 inches,				305	385	485	555
21 inches,					420	525	605
22 inches,					450	570	650
23 inches,					480	620	700
24 inches,					515	665	750
25 inches,					550	715	800
26 inches,							855
27 inches,							905

A study of a few pine trees in the woods of the University of Vermont resulted in the following volume table in cubic feet:

TABLE IV

Diameter breast high (inches)	Volume cubic feet
4	1.8
5	3.1
6	5.1
7	7.5
8	10
9	12
10	15
11	18
12	21

To reduce the number of solid cubic feet of wood on a woodlot to cords, divide by 90, because this division is based on the supposition that a cord of stacked wood (128 cubic feet) contains 70 percent solid wood or 90 cubic feet. Thus 500 solid

cubic feet = $5\frac{1}{2}$ cords, ($\frac{500}{90} = 5.5$). A study by the forestry

students of the University of Vermont showed that with white pine trees from 3.5 to 5 inches in diameter and from 30 to 55 feet in height, 28 trees were required to make a cord.

Yield table.—The two tables described above give the volumes of logs and trees. A yield table gives the volume of a whole forest of definite area, usually an acre. Such tables can only be constructed accurately for forests where most of the trees are of the same age; and have thus far been made entirely for pure forests. Yield tables are made by averaging together the volumes of a great many different acres of forests, the results being so tabulated as to give the amount of lumber or number of cords which such a forest will produce at any definite age.

The following yield table from Mensuration of the White Pine, published by the State Forester of Massachusetts, gives the average yield per acre of such stands at different ages on three classes of soils:

TABLE V. YIELD TABLE FOR WHITE PINE

Age	QUALITY I		QUALITY II		QUALITY III	
	1 inch boards	Cords	1 inch boards	Cords	1 inch boards	Cords
25 years	10,825	25.1	6,750	16.4	3,975	10.8
30 years	19,900	44.0	12,500	31.2	7,500	18.2
35 years	31,150	60.4	24,400	49.0	16,950	35.8
40 years	40,650	70.6	32,800	58.0	25,200	46.2
45 years	49,350	78.0	40,600	64.8	32,100	51.8
50 years	55,150	84.2	46,500	70.0	37,550	56.6
55 years	59,650	89.2	50,550	74.8	42,100	60.8
60 years	63,600	93.4	53,200	79.2	44,550	64.6
65 years	67,050	97.2	56,600	83.0	46,150	68.4

Growth tables.—Besides the tables giving volumes of logs, trees and forests, tables of growth are very instructive and are now being prepared for many of our more important trees. These may be in various forms and may show the growth in height, in diameter, or in volume.

The following growth tables illustrate very well the growth of pine in height and volume:

TABLE VI. GROWTH TABLES—GROWTH IN HEIGHT

Age	Upland pasture 73 trees feet	Rich lowland 109 trees feet	Sandy soil 16 trees feet	Wet swamp 47 trees feet
10 years	9	8	5	4
15 years	16	15	14	10
20 years	24	23	23	16
25 years	32	31	30	22
30 years	40	39	36	28
35 years	47	46	40	34
40 years	53	52	44	39
45 years	59	57	48	43
50 years	64	62	51	48
55 years	69	66	54	51
60 years	73	69	57	54
65 years	76	71	59	57
70 years	80	73	61	60
75 years	82	75	63	62
80 years	84	77	65	65
85 years	87	79	..	68
90 years	89	80	..	70
95 years	90	..	..	..
100 years	91	..	..	..

A study of the growth of pine seedlings in the woods by the forestry students of the University of Vermont, showed the height growth for the past six years as follows:

1904.....	3.8"	1907.....	6.3"
1905.....	5.9"	1908.....	5. "
1906.....	6.1"	1909.....	8.7"

This is only another way of showing that the growth is greater as the trees become older.

TABLE VII. GROWTH TABLES—GROWTH IN VOLUME

Age	Rich lowland 109 trees Cu. ft.	Upland pasture 73 trees Cu. ft.	Sandy soil 16 trees Cu. ft.	Wet swamp 47 trees Cu. ft.
10 years	.8	.6	.4	.3
15 years	1.8	1.2	.5	.4
20 years	3.0	2.0	1.4	1.0
25 years	5.5	4.5	2.5	1.6
30 years	9.0	7.5	4.0	2.7
35 years	13.5	11.5	6.3	4.0
40 years	19.5	16.6	9.3	6.0
45 years	26.5	22.0	12.5	8.3
50 years	35.0	27.7	16.0	10.7
55 years	43.5	34.5	19.8	14.5
60 years	51.5	41.7	23.6	18.6
65 years	60.0	49.0	27.5	23.0
70 years	68.0	56.0	31.2	27.2
75 years	75.5	....	35.3	31.2
80 years	84.0	....	39.0	34.8
85 years	93.5	....	42.8	38.0
90 years	....	....	....	41.0
95 years	....	....	....	43.5

It is evident from these tables that pine makes its best height growth on upland pasture where the trees stand closely together and crowd each other up; while the best volume growth is made on rich lowland. Both in height and in volume the growth on sandy soil was far below that on the pasture or lowland soils, thus overthrowing the common idea that pine does better on sandy soil than it does elsewhere. It is characteristic of sandy soils for the simple reason that it thrives there while other trees do not. It will be noticed that with the exception of wet swamps the height growth is considerably more than one foot a year.

PART III MANAGEMENT OF PINE FORESTS

PURE WHITE PINE FOREST

The most profitable forest for Vermont, except for the high elevations, is one composed of white pine with very little admixture of other species. Such a forest, in which one species constitutes 80 percent or over of the whole forest, is called pure. Plantations of pine are now being made extensively in Vermont, and there are also numerous pastures coming up naturally to young pine. On the whole the pine seems to be extending its range, especially in the White River, Connecticut and Passumpsic valleys. In the Champlain valley also there are many areas covered with pine. These stands are usually nearly even aged, i. e., the trees do not vary in age by more than a dozen years. The plan of treatment depends upon the age.

Pine 10 to 20 years old.—Oftentimes in these stands the pine has grown up under or with gray birch, poplar or some other tree of comparatively little value. There are sometimes as many as three thousand trees to the acre. These inferior species not only take up room but rub the pines and often seriously injure them. They should be cleaned out, leaving the pines unmolested. Such a thinning is called a "cleaning." The material cut is probably too small for use, so the cleaning calls for an investment. Much of this growth may be broken off easier than cut. No pines are cut at this period. It will take about two days' labor to clean an acre in this way, so if the wood is too small to use it means an investment of about \$3 an acre. Made in the fifteenth year this investment would amount at the legal rate of interest—6 percent—in the fiftieth year to the equivalent of an expenditure of about \$25 an acre. It is easy to believe that such

The age of standing white pine can be determined more accurately than that of any other tree by counting the whorls of branches which occur from four inches to thirty inches apart along the main trunk, and allowing four or five years for the first foot above the ground. Of course the age of any felled tree can be determined accurately by counting the rings which are made annually.

a cleaning would entail an added value to the property at least equivalent to this sum, enabling it to grow at least 3,000 or 4,000 feet more, and doubtless better lumber. The yield tables on page 118 of fully stocked stands of white pine show that at 50 years from 35,000 to 55,000 feet of lumber to the acre may be expected, according to the soil, worth from \$250 to \$500 per acre. Sales at prices between these two figures are on record. It is not advisable to prune pines at this period, for the limbs are needed to develop food and will be killed out if the trees are sufficiently close. If there are large openings—say fifty feet across—they should be planted up with pine transplants. Smaller openings should not be planted, as the little trees will be simply overtopped by those on the edge. In cases where the pine has grown in dense thickets without any admixture of other species, there is no call for a cleaning, but towards the twentieth year, after the lower limbs have died, a light thinning may be made.

Pine 20 to 50 years old.—When white pine has reached the age of twenty years it has a diameter, unless too much suppressed, of from 3 to 8 inches and the wood is, therefore, usable for fuel. At this period in the life of a pine forest a very fast growth is made, often as much as two feet a year in height. This fast growth means an intense struggle for existence where the trees are crowded. In order that the greatest possible amount of lumber be made it is necessary that the trees to be matured have a living crown at least one-third their total length.

In many of our forests the natural struggle for existence goes on so long that the number is too much reduced and the crowns so weakened that they cannot take advantage of the increased amount of light and air. It must be remembered that a tree never produces branches except at the top and for this reason it does not pay to leave crippled topped spindling trees. Many forest owners have the false impression that good forestry depends on the removal of the large trees, always leaving the small ones. As a matter of fact in forests under fifty years it

is usually the other way around. This common mistake about forestry is easily understood when it is realized that the selection system or diameter-limit method of final cutting is best understood, and that the lay mind does not distinguish between a thinning and final cutting. In the former case, which is the one under present consideration, the purpose is to develop the best pines. Consequently the small ones are cut out. The larger ones are now growing at their most rapid rate. If cut, the best growth would be lost and the smaller remaining trees would grow very little.

Table VIII illustrates this point. It is the case of a thinning in a quarter acre piece of pine about 25 years old belonging to C. D. Hazen of Hartford. It will be noticed that the trees cut were largely those of diameters 3, 4, and 5 inches, while the majority of those left are 4, 5, 6, 7 and 8 inches.

TABLE VIII. ONE-QUARTER ACRE PINE, 20 TO 25 YEARS

Diameter, breast high Inches	Number of trees left	Volume of trees left Cubic feet	Number of trees cut		Volume of trees cut Live and dead, cubic feet
			Live	Dead	
1	..	..	..	..	..
2	..	..	6	19	10
3	1	1.	21	48	65
4	26	30.	30	46	91.2
5	39	70.2	13	13	46.8
6	48	124.8	9	..	23.4
7	18	61.2	3	..	10.1
8	18	81.	1	..	4.5
9	8	47.2	..	..	..
10	7	54.6	..	..	..
11	1	10.	..	..	..
12	1	12.	..	..	..
Totals,	167	492	83	126	251.0

In this plot 45 percent of the standing trees are left and 55 percent are cut out; but it will be noticed that already 126 trees or 34 percent of all those in the plot were dead. After the thinning there were about 700 trees per acre left, which allows 62

square feet for each tree, equivalent to a spacing of about 8 feet each way. The percentage of wood left is greater; 5.5 cords or 66 percent of the wood is left; while 2.8 cords or 33 percent is removed. For a whole acre the stand is 33 cords.

Thinnings, if made properly in a fully stocked stand, should be repeated every eight or ten years. Roughly speaking, thinnings may be made when the forest is 20, 30 and 40 years old. In the last two thinnings some lumber would be obtained, considerably increasing the profit of the operation. In case no cleaning had previously been made the first thinning would remove all weed trees. All dead pines which can be utilized should be cut, suppressed trees which are evidently dying, and enough of the intermediate trees so that the crowns of the remaining trees will not crowd until they have grown several years.

Plates 5-10 opposite page 128 and the diagrams on pages 104-109 illustrate such thinnings being made in the pine forest of the University of Vermont, where the ages vary from 25 to 35 years. The materials removed from this stand are cut into three grades according to their sizes and are sold piled in the woods at the following prices: Logs, six inches and over at the top, \$12 per thousand; stave wood, 4 to 6 inches at the top, cut in 5 foot lengths, \$3 per cord; cord wood under 4 inches, cut in 4 foot lengths, \$1.50 per cord. Thinning is a good paying proposition at such prices.

Pine forest over 50 years old.—The Massachusetts bulletin containing the yield table given above indicate that pine plantations afford the greatest profit on the investment when cut at the age of 50 years. As there are no plantations approaching this age in Vermont, we have to consider only natural forests. Here there is no cost of planting to be compounded and hence the financial rotation is somewhat changed.

Under ordinary circumstances where the trees are thrifty clean cutting at 50 years is not to be advised as compared with some system of natural reproduction, usually the "stand system" described on pages 113 and 114. About one-third of the trees

are removed at 50 years, or preferably in the year of a good pine seed crop, leaving the large topped trees that will have the fullest crop of seed and some of the best formed trees that will make the best grades of lumber.

Table IX illustrates the application of this method in a Connecticut pine lot where the total stand of pine 55 years old per acre was 39,400 feet to the acre and 8,400 feet was removed.

TABLE IX. SURVEYS OF THREE ONE-QUARTER ACRE PLOTS

TREES LEFT			DEAD TREES		OTHER TREES TO BE CUT	
Number of plot	Num- ber	Volume board measure	Num- ber	Volume board measure	Num- ber	Volume board measure
1	51	9,000	14	965	18	1,550
2	42	8,250	8	630	9	770
3	47	6,050	10	1,305	20	1,085
Sum,	140	23,300	32	2,900	47	3,405
Total per one-quar- ter acre,	47	7,767	11	966	16	1,135
Average per acre,	188	31,068	44	3,804	64	4,540

Total volume to be cut per acre, 8,404 board feet.

In this forest of seven or eight acres the profits from this preparatory cutting were as follows:

51,800 feet @ \$6 stumpage	\$310.80
35 cords @ \$1.25 stumpage.....	43.75
	<u>\$354.55</u>

The lot was about three miles from the railroad and twelve miles from the city of Hartford. It was in poor condition, as there were many openings and the stand was accordingly much less than it should be. Nevertheless it had produced at the rate of about 800 feet of lumber per acre per annum, or an income equivalent to \$4.80 per acre. The returns from this cutting were between \$40 and \$50 per acre.

Table X shows the trees marked for such a preparatory cutting in a pine forest belonging to the University of Vermont, where the trees are from 60 to 70 years old.

TABLE X. ONE-HALF ACRE WHITE PINE, 60 TO 70 YEARS OLD, BURLINGTON, VT., TREATED UNDER THE STAND SYSTEM—REPRODUCTION CUTTING

Diameter breast high, inches	Board feet per tree ¹	TREES TO BE LEFT		TREES TO BE CUT	
		Number of trees	Total board feet	Number of trees	Total board feet
6	30	..	...	2	60
7	50	..	...	2	100
8	65	..	...	3	195
9	105	..	...	3	315
10	125	3	375	9	1,125
11	170	4	680	15	2,550
12	200	4	800	3	600
13	235	12	2,820	4	940
14	265	14	3,710	5	1,325
15	300	9	2,700	6	1,800
16	335	10	3,350	2	670
17	420	9	3,780	1	420
18	465	3	1,395	..	...
19	510	..	...	..	...
20	555	3	1,665	..	...
21	605	..	...	..	...
22	650	..	...	..	...
23	700	1	700	..	...
Total,		72	21,975	55	10,100
		55	10,100		
		127	32,075		
		57%	68%	43%	32%

¹The volume table (page 117) as applied on this plot has given results somewhat too high, as the trees are more spindling than the average, owing to the long period of crowding. Allowing 10 percent discount for this and for decay and imperfections, the total stand per acre here was 57,600 board feet.

It will be seen that in this forest 60 to 70 years old having a stand of nearly 60,000 board feet per acre, 43 percent of the number of trees are marked for removal, amounting to 32 percent, or one-third, of the standing lumber.

After the preparatory cutting has been made at about 50 years, at least two seed years, and possibly three, should be allowed to pass before the main reproduction cutting is made. The forest will then be about 65 years old, with a considerable understory of little pines started. At least half of the standing trees should be removed at this time, and it is usually the most profit-

able cutting. As the previous cuttings have not materially reduced the growing stock, it would be safe to estimate the cut per acre at this time in a fully stocked stand at between 20,000 and 30,000 feet board measure, producing a revenue at \$6 per thousand of \$120 to \$180, or at \$8 per thousand of \$160 to \$240. The reproduction already started is given plenty of light by this cutting and the additional openings are seeded up from the remaining trees.

By the time the remaining trees are 75 to 80 years old the final cutting can be made. While there are usually fewer trees to be cut at this time, by reason of their size and better quality, this operation may be the most profitable of all. The revenue from it would usually vary between \$100 and \$250 an acre. If there are any openings made by the final cutting which do not seem likely to reproduce, they should be planted. This will usually be unnecessary if the old trees are cut in a seed year.

The following table summarizes the probable revenue from fully stocked pine forests on Vermont soils, under management from youth up by the stand system:

Age	Stumpage value of material removed per acre
Thinnings made between:	
1 and 40 years might be expected to yield	
an income of	\$40-\$50 per acre net profit
40 and 50 years might be expected to yield	
an income of	\$40-\$50 per acre " "
Semi-final cuttings made between:	
50 and 65 years might be expected to yield	
an income of	\$100-\$200 per acre " "
Final cuttings made between:	
65 and 75 years might be expected to yield	
an income of	\$100-\$250 per acre " "
	\$280-\$550

When the final cutting is made under this system the forest is already well reproduced with a stand of pine from 1 to 25 years old, with some trees even older which started before the preparatory cutting, so the first thinning in the next generation can be

made soon after if not in connection with the final cutting of the old growth. It will be seen that the total returns from a well managed pine forest in 75 years will be greater than represented above, since the money taken in at the various periods, put at interest, would be much increased by the end of the rotation.

Strip system applied to pine.—In large tracts of pine the strip system described on page 114 can be advantageously applied. However, there are no such tracts in Vermont so far as the writer knows, and the stand system is unquestionably superior for small areas.

In the introduction of forestry at this time many forests already advanced in years will come under treatment for the first time. Necessarily the incomes from such will be much less than from forests well managed from youth.

Pasture pine.—Quite a definite form of pine is the branching, bushy topped tree that grows out in the open pastures. Such trees in some regions are variously called "cabbage" or "bull pine." The question as to what should be done with these trees often occurs in the management of such a tract for forestry purposes. They will never be of much value for lumber, but are just the kind of trees that produce large quantities of seed. For this reason, if the tract is only partially stocked, they should be kept for seed purposes. In fact from the standpoint of seed collection they have a considerable value. Cones being worth about 50 cents a bushel, such a tree may easily yield from 50 cents to \$1.50 every three or four years. Even with but twenty trees to the acre this would mean a periodic income of from \$10 to \$30 an acre, or an average annual income from seed alone of \$2 to \$10 an acre. The writer has on one occasion purchased such seed trees individually, paying \$1 apiece in addition to the land where the timber was not included. These, however, were large trees.

There comes a time when the young growth on the old pastures closes up the openings. These large spreading trees are



PLATE V

GROUP I. Before thinning. White Pine 25 to 35 years old. Trees to be removed: 1, diam. 5", ht. 40'; 2, diam. 5", ht. 49'; 4, diam. 4", ht. 18'; 6, diam. 11", ht. 52'; 9, diam. 4", ht. 40'; 11, diam. 4", ht. 40'; 13, diam. 6", ht. 48'; 15, diam. 6", ht. 42'; 18, diam. 4", ht. 54'.



PLATE VI

GROUP I. After thinning. Trees left: Nos. 3, 5, 7, 10, 12, 21, 22, 24, 16; not showing in view, 17.

PLATES V. and VI on the University of Vermont forest lands at Burlington.



PLATE VII

GROUP II. Before thinning. White Pine 30 to 35 years old. Trees to be removed: 80, diam. 4", ht. 44'; 84, diam. 7", ht. 45'; 88, diam. 6", ht. 49'; 96, diam. 6", ht. 46'; 100, diam. 5", ht. 31'; 103, diam. 4", ht. 20'.



PLATE VIII

GROUP II. After thinning. Trees left: Nos. 81, 82, 83, 85, 86, 87, 89, 90, 91, 92, 93, 94, 95, 97, 98, 99, 101, 102, 104, 105.

PLATES VII and VIII on University of Vermont forest lands at Burlington.



PLATE IX

GROUP III. Before thinning. White Pine 30 to 40 years old. Trees to be removed: 1, diam. 5"; 3, diam. 9"; 6, diam. 7"; 11, diam. 11".



PLATE X

GROUP III. After thinning. Trees left: Nos. 2, 4, 5, 7, 8, 9, 10, 12, 13. PLATES IX and X on University of Vermont forest lands at Burlington.



PLATE XI

Mixed Forest of White Pine and Oak 75 to 150 years old, Brandon, Vt.
Large pine marked for cutting. Others left for seed and more
growth. Stand 8,000 to 10,000 board feet per acre.

then no longer needed for seed as much as their room is needed by the better trees. They should then be cut out with as little damage as possible to the surrounding growth, this cutting to be done when the trees are in seed in order to get the increased value of the seed crop.

Uneven aged pine.—Conditions like the above result in a stand of trees of different ages which is somewhat more complicated to handle than are those stands wherein the trees are all of the same age.

As indicated elsewhere the first measures employed are to close up the large openings, never planting so near to large trees that the seedlings will be suppressed; and to remove the cabbage pines. This in itself tends to even up the age of the forest. Thinnings should be made in the thickets and every operation made with a view of eventually transforming the forest into one of relatively even age.

PINE IN MIXTURE WITH OTHER SPECIES

There are, of course, many forests in Vermont where pine is mixed with other species. The writer has seen a splendid mixture of pine and spruce in Sunderland and a mixture of red and white oak with pine in Brandon (see opposite plate, p. 128). The pine is so much more rapid growing than are these other species that the preparatory and reproduction cuttings should be made with a view to pine reproduction. In the management of the Brandon forest just referred to, the aim of getting as much pine reproduction as possible with some oak is realized by leaving a few clumps of the younger pine trees, from 50 to 75 years old, and an occasional thrifty oak. All birches and poplars are removed. There are birch and poplar forests with a scattering of white pine in the White River valley. When the poplar reaches a diameter of ten inches it should be cut out, as it is short lived; and some or all of the birch may be cut at the same time; but three or four pines to the acre should be left for seed so that in the next generation pine will form a bigger percentage of the mixture.

WHITE PINE SEEDING

Few forest trees bear seed every year and the white pine is rather more irregular than are most trees in this regard. There is a common saying that the pine bears a seed crop only once in seven years. This notion, however, is incorrect. There was a good seed crop in Vermont in 1907, and another the past fall—1910. This latter crop was very uneven, for in certain localities—as Essex and Colchester—there was a good crop, while in other nearby regions—as Milton—there were almost no cones. It takes two years for the pine cones to mature. At the end of the first season the cones are about one inch long and of a purplish color. The mature cones begin to open early in September and the seed blows out and is carried by the wind for considerable distances. As there are two seeds on each scale of a cone, there may be eighty or more seeds in a cone. Usually about one pound of seed is secured from a bushel of cones. In order to collect the seed it is necessary to gather the cones before they open. This can best be done where lumbering in pine is being done in the fall, picking the cones from the tops on the ground. In most regions the squirrels help materially by dropping the cones to the ground before they have opened. While this is a help to the collector it is a damage to natural seeding. Some large topped pines will yield from two to three bushels of cones, which carry anywhere from 50,000 to 100,000 seed. It will be seen from this that a few such trees scattered over a tract are important factors toward its restocking. The seed is carried in large quantities twice the length of the tree and much of it considerably farther. It germinates best where there is plenty of light, as in an open pasture at the edge of the woods, or in an opening caused by windfall. The little seedlings require a great deal of light and will soon die if they do not have it.

These facts are important reasons for making cuttings in a pine forest the season following a seeding. On account of the length of time required to mature the cones it is always possible

to know a year ahead when there is to be a good crop, and the harvest should be planned accordingly. If the cutting is made in the fall or winter following seeding, the ground is covered with seed, which germinates well on the soil stirred up by lumbering and grows well with the increased light. If made the year before, the seed from these trees will be lost and if made the year later, it would have germinated and mostly died. This explains why it is that occasionally one finds a splendid second growth of pine following the cutting of pine, but that more often one does not.

Cones are often formed on very young pine trees, but until the trees become thirty years old there is either no seed in these cones, or else the seed is apt to be sterile.

MARKET FOR PINE

Occurring as it does chiefly in the accessible valleys of the State, white pine is always marketable at good prices; and almost everywhere the tops and limbs can be sold for fuel. The average prices paid for pine logs delivered at the mill in 1909 were \$15.50 per thousand in Bennington county; \$14.50 per thousand in Chittenden county, and \$13 per thousand in Caledonia county. Doubtless a larger percentage of the pine in the latter county is of second growth, hence the lower price. Pine tops vary in value from \$2.50 to \$3 per cord delivered.

Cost of logging.—The cost of cutting and skidding varies with the size of the trees and the topography, between \$2 and \$3.50 per thousand. Hauling depends on the distance and varies between \$1 per thousand for hauls of less than one mile to \$3.50 for hauls of six miles. This makes the logs cost from \$3 to \$7 at the mill, for there are few pine lots over six miles from a mill. The stumpage would, therefore, be worth to the owner from \$6 to \$12, but the latter price would only be obtainable for the best of old growth very near the mill. Most mills custom saw pine for \$3 per thousand. Of course where stumpage is sold to a lumberman a profit must be allowed him on his operation. This

is equivalent to paying him a commission for taking charge of the lumbering. The experience of lumbermen who have tried thinning pine indicates that it costs about fifty cents per thousand more for cutting and skidding in that way than for cutting clean. On page 124 are the prices which were obtained for the thinnings made in the University pine woods.

INSECTS AND DISEASES AND OTHER ENEMIES OF WHITE PINE

There are a number of troubles of the white pine which are commonly confused in the lay mind, the most conspicuous of which are due to two insects: the pine weevil and the pine bark aphid.

WHITE PINE WEEVIL (*Pissodes strobi*)

The white pine weevil is generally distributed wherever the white pine occurs and works considerable damage thereto. In Vermont it is especially injurious near Proctor.

Form of damage.—This insect seldom kills the trees but invariably works in the main shoot, causing it to wither and die, usually in July or early August. The next year one of the side branches straightens up and forms the leader, but there is always a slight crook in the tree. In badly infested regions the same tree is often attacked repeatedly and the numerous crooks give it a much deformed and stunted appearance. Of course its value for timber purposes is much diminished. The insect seems to prefer trees from three to thirty feet in height, though it occasionally attacks tall trees. Its ravages are worse in the southern range of the species than in Vermont.

Appearance.—The adult is a reddish brown beetle about half an inch long with a pronounced snout. The pupa is creamy white and of about the same length as is the adult. The grub is also white and of varying length up to one-fourth of an inch, according to development. The infested top is badly decayed at the close of the season and is cut up with tunnels filled with borings. The first sign of the attack is disclosed by the wilting of the needles.

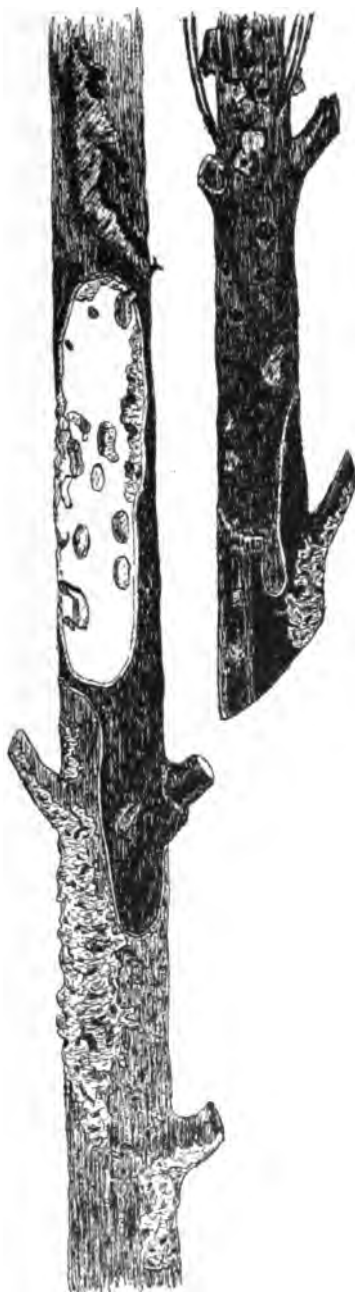


FIGURE 4

WHITE PINK INSECTS

Upper right hand: twig from top of pine seedling killed by weevil. Note the borings, shown also at interior (on upper left hand). This also shows larvae of weevil. A view of the adult weevil much enlarged appears above. At base of left hand twig appears masses of pine bark aphids.

Life history.—The beetles deposit their eggs under the bark of the main shoots in May or June, and when the grubs hatch after a week or two they bore inward and in a downward direction to the pith. The grubs are much reduced by natural enemies, mostly parasitic insects. They transform into pupae and adults and during July and August of the same year, when the adults are fully matured, they bore their way out and seek suitable places in which to pass the winter.

Treatment.—The only way of fighting this insect is to cut off the infested top during June and July before the beetles have escaped. The safest way of destroying the weevils is to burn these tops; but as they often contain also a large number of minute insects which prey on the weevil a modification has been suggested by Hopkins. A perfectly tight box or barrel is prepared with but one opening. The infested tops are placed in this and the opening covered with a very fine wire mesh, so fine that the beetle cannot escape, while the parasites, which are much smaller, get out and attack other weevils. The box must not be exposed to weather as it will check and the weevils will escape. Either form of treatment must be repeated several successive years, as it is impossible to catch all the weevils in a single season.

PINE BARK APHID (*Chermes pinicorticis*)

Form of damage.—This plant louse is sometimes present in such large numbers on pine stems as to weaken the vitality of the tree, resulting in a sickly condition and, occasionally, in the death of young trees.

Appearance.—The presence of this insect is easily recognized by the cottony appearance on the twigs and in some cases all over the trunk of the tree. It is sometimes mistaken for the exudations of pitch.

Life history.—The eggs begin to hatch early in May, the young emerging in large numbers from the bulbs of woolly matter spread over the bark. They are almost too small to be seen individually by the naked eye, but are very numerous at this time.

They soon attach themselves to the tender bark of young twigs, increase rapidly in size, become dark brown or black, and exude a substance which nearly hides them. Maturity is reached about the last of May and the wingless females deposit eggs for another brood. Later in the year winged females occur and during a summer several broods may occur.

Treatment.—This aphid has several natural enemies, the most effective being certain varieties of ladybugs. Where there is a hydrant near the insect can be washed off with a forcible stream of cold water, otherwise a spray of kerosene emulsion or whale oil soap is efficient. For the latter 1 pound to 4 gallons of water is used.

PINE LEAF BLIGHT¹

The cause of the pine leaf blight has been diligently sought but is still not well understood. About all that can be said is that it is not due to an insect and apparently not to any fungus, but probably is caused by unfavorable weather conditions such as winter injury due to extremely cold weather without much snow, or to extremely dry summers. This blight is characterized by the death of the end of the needles, from one-fourth to one-third thereof turning bright reddish brown. Sometimes the whole needle dies, giving the tree a brown appearance. This usually occurs in July. This condition was particularly widespread during the summer of 1907, and many feared the pine forests were doomed. Few trees died, however, and conditions were much better the next year. By 1909 it had practically disappeared in most sections of Vermont, but curiously enough was much worse in the region about Burlington.

The pine woods belonging to the University of Vermont were carefully examined in August, 1909, and the affected trees were numbered. Another examination made in the summer of 1910 showed seven additional trees diseased, while of the 112 previously found to be diseased the conditions were as follows:

¹U. S. Dept. Agr., Bul. Pl. Ind., Circ. 35 (1908).

	Number of trees	Percent of trees
Dead	6	5.3
Recovered	55	49.1
Recovering	13	11.6
Same as previous year	38	34.0
	112	100.0

This study shows that the condition of the stand is much improved, which would indicate that dry summers may have an important bearing on the malady, since the summers of 1908 and 1909 were very dry, while that of 1910 was normal in respect to rainfall.

THE WHITE PINE BLISTER, OR EUROPEAN CURRANT RUST¹
(*Peridermium strobi*)

The demand made upon the state nursery by would-be planters for pine seedlings in 1909 so far exceeded the supply that 350,000 white pines were imported from Europe, no American nurseryman being able to make equal prices. The Massachusetts, Connecticut and New York state forest services made similar importations. The trees were in part distributed about the State. While planting was going on in New York, it was discovered that some of these imported seedlings were infested with a common european fungus disease, the white pine blister rust, a malady entirely different from the pine leaf blight just described and not heretofore discovered on American pines. A careful examination showed some indication of the disease on a few of the Vermont imported seedlings. Fortunately it is a comparatively easy task to eradicate this malady, since its spores must spend part of their life on the currant or gooseberry bush. As soon as it was discovered that there was a chance that this disease might exist on the imported nursery stock, a careful examination was made of every such plantation throughout the State, and all currant and gooseberry bushes, whether wild or cultivated, within five hundred feet thereof were

¹Confer U. S. Dept. Agr., Bu. Pl. Ind., Circ. 38 (1909).



FIGURE 5. THE WHITE PINE BLISTER

Midway up stem of seedling at left shows the swelling characteristic of the disease. The branches are similarly affected. The spore bags are also shown, which appear in the spring and are orange yellow in color. A swollen stem of pine killed by the rust appears at the right. The leaf is that of a currant, showing on its underside the spores which spread from the currant to the pine in August. The small ones are yellow, the larger ones, brownish.

destroyed. In the inspection made in the spring of 1910 the disease was found in only a few of the plantations and in these only about 1 percent of the trees showed its evidence. The diseased plants were at once destroyed. It was also found on a plantation of white pine made about three years previously on the Billings estate in Woodstock, where trees were used which were purchased from a Massachusetts nurseryman and evidently imported by him.

The only time of the year when this disease can be unmistakably recognized is the spring. The fruiting bodies which occur on the stem and are of a bright orange color and hence easily distinguishable, began to appear in 1910 about the middle of April, and some were found as late as the first week in June. Such buyers as have planted any of these imported trees should be on the lookout in the spring, although another inspection will be made in 1911. It would be well to destroy any dead trees found at other times, although this may not be necessary, and especially seedlings which have an unnatural swelling of the stem. Of course all gooseberries and currants, either wild or cultivated, located within a couple of hundred yards of the plantation, if any such there be, should be destroyed to prevent the spread of the disease. The state forest service has endeavored conscientiously to do this, but it is conceivable that some bushes may have escaped notice.

FOREST FIRES

Fires are disastrous to any forest, but particularly so to pine. The ground cover of needles burns readily and all the small seedlings and saplings are killed. The thick bark of the old trees enables them at times to escape a surface fire, but they are usually severely scorched, especially on slopes where the flames lap around the trunk and scar the upper surface. All fires should be prevented. The methods of fire prevention and combat have been discussed in a previous bulletin and need not be repeated here.

GRAZING

Cattle seldom if ever eat pine needles, but they do a great deal of damage to young seedlings by trampling on them and rubbing against them in summer. A good example of this damage is afforded on the University of Vermont property, where some splendid reproduction has been nearly destroyed by cattle. All grazing cattle should be excluded from forests in the process of regeneration. After such regeneration is accomplished there will not be enough grass in the forest to warrant pasturing. Pasturing and forestry can never be practiced satisfactorily on the same land.

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UNIVERSITY OF VERMONT
AND STATE AGRICULTURAL COLLEGE

VERMONT AGRICULTURAL
EXPERIMENT STATION
BURLINGTON, VT.

BULLETIN NO. 157
MARCH, 1911

The Damping Off of Coniferous Seedlings.

BURLINGTON:
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1911.

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*In cooperation with Bu. An. Ind., U. S. Dept. Agr.

BULLETIN 151: PLANT DISEASES

Twenty Years' Spraying for Potato Diseases Potato Diseases and the Weather

BY B. F. LUTMAN

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STUDIES IN PLANT DISEASES

The year 1910, like the three preceding it, was inclined to be rather dry during the summer months and there were no periods of excessive and continued rainfall. To this fact is largely due the absence of any marked outbreak of fungus plant diseases. Those that occurred are the ones that, like the poor, are always with us, every season. The year 1909 was a fairly average one as regards rainfall and temperature, so the perennial plants, such as the trees and shrubs, started into 1910 in fairly good condition. It has been repeatedly observed at this Station that, following a very dry summer, numerous reports are made the next season of the partial dying of trees, a result due to the injury to their root systems wrought by the drought.

In 1910, therefore, these nearly average conditions tended to prevent any serious physiological maladies. Only one was observed or reported; but this was quite serious. The leaves on many of the oaks suffered quite severely during August, and by the first of September a third of them were dead. The scorched appearance seemed due to lack of water brought about by excessive transpiration and an enfeebled root system. No fungi were found. A similar condition was frequently reported during the previous season among the maple trees, many of which died without visible reason, save lack of water. The oaks, however, did not suffer seriously at that time.

The *pear and apple scab* is still the most persistent and frequent of orchard fungus enemies, but the better growers are rapidly learning that clean and perfect fruit brings much better financial returns than does that which is scabby and misshapen, and that such can be produced if proper care is taken. This means that the trees must be sprayed at least three times, either with the weak lime-sulphur mixture or with weak bordeaux mixture. These fungicides should be applied just before the blossoms open, just after the petals fall, and at least once afterward (see bulletin 113, pages 96, 103).

Pear blight does not seem to be as common as formerly, due probably to the fact that growers have found out that it may be exterminated by pruning out the dead limbs, either in the fall or the early spring before the sap begins to flow. This pruning must extend several inches back of the point where the limb is dead, however, and the tools used should be disinfected after each operation, by dipping them in a solution of one part of commercial formalin to ten parts of water.

In spite of the ease with which *black knot* may be prevented and its destructiveness to plum and cherry trees when once it attains a good start, it is still found in many Vermont orchards. The same procedure as is used against the pear blight will free these trees of this disease; and it is an easier task, since the constant disinfection of tools is not essential.

Apple rust has never become an important factor in Vermont orcharding, yet it was reported several times during the summer, in one case entire trees in an orchard being ruined by it. The removal of the red cedar, the secondary host that harbors the fungus, is not practicable in most parts of the State; and spraying is not entirely effectual.

Oat smut is a disease from which Vermont fields have been comparatively free, at least in comparison with western conditions where the loss in some cases runs as high as 15 percent of the entire crop. Yet several fields were noted in this State where the number of infected heads must have amounted to 5 or 10 percent of the entire number. These oats, grown from Vermont seed, show that smut is again becoming an important disease here. The ease with which it may be prevented by treating the seed oats over night with a weak formalin solution (1 pint of formalin to 30 gallons of water) should be known to every farmer who raises oats. It can be done at any time during the winter and is a certain preventive (see bulletin 113, page 100).

Club root of cabbage is spreading throughout the State and before many years it will be found in nearly every garden where

this crop is raised. The disease is spread largely through the sale of cabbage plants sent to market in greenhouse flats, but infected soil may be carried on the shoes or in the hoofs of horses. When the soil has once become inoculated with the fungus, it is years before cabbage, cauliflower, turnips or any member of that group of plants can be successfully grown again. If plants for setting out are bought instead of being raised, the buyer should be sure that they have not been grown in infected soil.

Pea and *chrysanthemum* plants affected by *wilt* were sent to the Station several times from different localities. The cause of the trouble seemed to be the growth of one of the *Fusariums*.¹

Potato diseases of any sort were rare around Burlington, about the only abundant one being black-leg. This occurred on one end of the field grown on the college farm and was reported to us as present in fields in other parts of the State. Neither early nor late blight were found in this vicinity. Tip-burn appeared on the unsprayed plants during late August and early September, but was not markedly destructive. From other parts of the State have come reports and specimens showing severe attacks of late blight. From along the Connecticut river, where the dense fogs favored its early appearance, blighted leaves were sent early in July. Bad cases of late blight associated with the resulting tuber rot were reported from several towns in the more mountainous regions. A rather interesting fact was brought out in connection with some of these tubers sent for diagnosis. The tubers were rotting badly in storage and betrayed all the appearances of typical *Phytophthora* infection, such for example as dark sunken areas; yet continued efforts to cause the *Phytophthora* to appear, by the customary method of splitting the tuber open with a sterile knife and afterward keeping it in a moist chamber, were without results, save in a very few cases. No abundant mycelial development appeared along the inner edge of the brown sunken spots and the scanty fungus growth

¹ In this connection see Bul. 157 on "The damping off of coniferous seedlings," caused by a similar fungus.

which did show apparently consisted solely of saprophytic species. The reasons for this situation were not clear, but it may have been in some way a result of the storage of the potatoes after digging, or of some peculiar weather conditions occurring during September and October.

POTATO SPRAYING

The 1910 trials were made with a view of continuing the studies on the effects of bordeaux mixture on the potato plants themselves rather than of its effect as a deterrent against disease. The results of 19 years of spraying have shown that bordeaux mixture does two things:

1. It very efficiently protects the plants from the attacks of the early and of the late blight.
2. It seems to serve in some way as a stimulus to the plant, so that it remains green from one to two weeks longer than do the unsprayed ones and, also, yields more and larger tubers.

The season of 1910 was an admirable one in which to study the latter phase of the bordeaux problem, for no blights appeared as disturbing factors. Hence any beneficial results wrought by the use of the bordeaux were necessarily due solely to its effect on the potato plant itself and not to the fungal attacks which it may have prevented.

An attempt was made in the 1909 trials¹ to ascertain the particular constituent of bordeaux mixture that produced the stimulus. Plots were sprayed as follows:

- (1) With the usual 5-5-50 bordeaux mixture (i. e. 5 pounds copper sulphate, 5 pounds lime, 50 gallons water).
- (2) With 4 pounds iron sulphate, 2 pounds copper sulphate, 6 pounds lime in 50 gallons of water.
- (3) With 5 pounds iron sulphate, 5 pounds lime in 50 gallons water.
- (4) Plants unsprayed, but dusted with paris green and lime.

Iron sulphate occurs as an impurity in commercial copper sulphate. Certain German investigators having claimed that the beneficial effect of bordeaux mixture is due to its small content of iron sulphate, plots 2 and 3 were treated therewith. The

¹Vt. Sta. Bul. 153 (1910).

yield of potatoes from those plants sprayed with either of the mixtures containing copper was greater than that harvested from the plots treated either with lime or with iron sulphate. The increased vigor of the plants as shown by the larger yield seemed due to the effect of the copper on the leaves.

Two physiological effects of the copper on the plants were noted:

(1) The bordeauxed leaves were thicker and of a darker green color than those which were left unsprayed, apparently indicating that the plant was healthier and, on account of its greater amount of chlorophyll, producing more starch.

(2) The plants thus treated suffered less from tip-burn than did those not bordeauxed and lived from ten days to two weeks longer, apparently indicating that transpiration is retarded. The question now arises whether the increased quantity of tuber yield is due to an actual stimulus of the plants throughout the growing season, or whether it is due to the prolongation of life. There can be no question that an increase in yield results when Vermont potatoes are sprayed with bordeaux. Yet many of the German stations now seem to hold that in northern European climates the bordeaux mixture may so injure the crop as to depress the yield.

The question then is: Does the plant that has been sprayed produce from day to day more starch than does the unsprayed one because of such spraying, or does it produce more starch because it lives longer? The trials of 1910 were conducted primarily with the intention of contributing to the answer of this question. A sufficient number of plots were sprayed and an equal number left unsprayed, so that diggings might be made at intervals throughout the summer and yields compared. If the copper is a benefit, if it increases the ability of the plant to fix carbon dioxid and to form starch, that stimulus should show even in August and September in the increased yield of the tubers from the plants so treated. On the other hand, if the bordeaux has no such effect, or if, perhaps, it induces a

slight injury to the plant, these early harvests in August and September should show no larger, indeed possibly smaller, yields on the bordeauxed plots than on those left untreated.

To guard against the possibility that the stored carbohydrate material had not yet been transferred to the tubers, but had in part remained in the stem and leaves, the tops were weighed in the earlier harvests as well as the tubers. Naturally it was impossible to take this precaution in the final harvest at the close of the season, since the tops were all dead; but, doubtless, the necessity thereof was less imperative.

The combination of iron and of copper sulphates proved nearly as effective in 1909 in keeping the vines green as did the straight bordeaux. It would seem that so far as stimulating the plant is concerned, the iron-copper sulphate mixture is practically as serviceable as is bordeaux, since the yields from both sets were practically identical. The fungicidal value of this mixture has not been determined, hence plots were sprayed therewith as a subsidiary experiment, in case the season should be a wet one and blight so prevalent as to render valueless the principal test.

In order to produce these effects noted on the sprayed plants the copper must be absorbed by the leaves. If the stimulus is a local one, limited to the particular leaves touched by the spray, the effect would be much less than if the copper after being absorbed was distributed over the whole plant, thus making the stimulus a general one. With this question in mind the plants on one of the plots were sprayed on their lower leaves only.

METHODS

Green Mountain potatoes were used as seed, and were sprayed July 11, July 27, Aug. 15, Aug. 23, and Aug. 30, as follows:

- (1) Three plots were left unsprayed to serve as checks.
- (2) Three plots were sprayed with 5-5-50 bordeaux mixture, a half pound of paris green being added as an insecticide. Application was made at the rate of about 250 gallons per acre.

(3) One plot was sprayed with a mixture composed of four pounds of iron sulphate, two pounds copper sulphate and fifty gallons of water, to which one-half pound of paris green had been added. Application was made at the same rate as with bordeaux.

(4) Only the lower half of the plants on one plot were sprayed with the 5-5-50 bordeaux mixture.

Additional applications of paris green and lime were made several times during the summer to kill the potato beetles which were fairly abundant.

No early or late blight developed during the season and no tuber rot occurred. Some black leg was observed at one end of the plots, but as this extended in a narrow strip of about uniform width across all of the experimental area and was not very serious in its effects on the plants, no account is made of it.

RESULTS

Harvests were made at three different times during the fall: September 2, September 16, and October 20.

The first harvest (September 2) consisted of the tubers from a plot sprayed with bordeaux mixture and those from a control plot.

	Marketable tubers per acre	Small tubers per acre	Total per acre
Sprayed with bordeaux mixture	167.9 bushels	26.9 bushels	194.8 bushels
Control	130.5 bushels	39.5 bushels	170.0 bushels

At this time the unsprayed plants had already suffered considerably more from tip-burn than had the sprayed ones. This was not so evident in the weight of the tops, however, as the average weight of the unsprayed tops was .7533 pounds, while that of the sprayed tops was .8085 pounds.

The second harvest (September 16) of two similar plots gave the following results:

	Marketable tubers per acre	Small tubers per acre	Total per acre
Sprayed with bordeaux mixture	275.8 bushels	24.0 bushels	299.8 bushels
Control	177.6 bushels	33.2 bushels	210.8 bushels

As compared with the results attained 14 days earlier the sprayed plants were much greener and more free from tip-burn than were the unsprayed ones. The average weight of the green tops of the control plants was at this time only .341 pounds, and the dry weight, .0552 pounds, while that of the sprayed plants averaged .666 pounds per plant, and the dry weight, .164 pounds.

The final harvest was made October 20. At this time all the plants, both sprayed and unsprayed, were dead and no attempt was made to weigh the tops.

	Marketable tubers per acre	Small tubers per acre	Total per acre
Sprayed with bordeaux mixture	220.7 bushels	19.6 bushels	240.3 bushels
Sprayed with bordeaux mixture plus iron sulphate	226.5 bushels	26.0 bushels	252.5 bushels
Sprayed with bordeaux mixture on half of the plant	208.7 bushels	21.4 bushels	230.1 bushels
Control	177.5 bushels	24.6 bushels	202.1 bushels

The results attained in the two September harvests would indicate that even early in the season, bordeauxed plants store more starch in their tubers than do those not thus treated. While the plants themselves both from the bordeauxed and the control plots were of approximately the same size, as indicated by the average individual weight, the slight difference of .0533 pounds being due to the small excess of tip-burn on the unsprayed plants, the weight of the tubers at this time was 24.8 bushels per acre in favor of the potatoes to which the bordeaux had been applied. This would seem to indicate that during the months

of July and August while the tubers were growing that the unsprayed plants were not able to fix as much carbon dioxid and transform it into starch as were those that had not been so treated.

The conclusions that may be drawn from the harvest of September 16 at this time are not as decisive as those of September 2, as the tip-burn had made rapid progress on the unsprayed plants during the intervening two weeks and the individual plants on the control plot were only half as heavy as those on the sprayed plots. At the same time the sprayed plants yielded 89 more bushels of tubers per acre than did those on the control.

The harvest of October 20, made when all the vines were dead, confirms again the results of the past 19 years' spraying of potatoes at the Vermont station. Bordeaux mixture, even in years like 1910 when no blight occurs, increases the yield of the plants to which it is applied. This increased yield is always sufficient to pay for the cost of spraying operations. Spraying is to be regarded as an insurance that pays for itself. If the blights are prevalent, the potatoes, if thoroughly sprayed, are insured against loss therefrom; if the season is a dry one and no disease occurs, still the crop will be enough larger to pay for all the cost of spraying. The careful potato sprayer wins either way, no matter what the weather or disease conditions.

From these results it would appear also that the application of the iron sulphate-copper sulphate mixture has practically the same effect on the vines as does the ordinary bordeaux. In fact this year the plots so sprayed yielded more than did the bordeauxed ones. Last year the yield from the bordeauxed plots was 243 bushels per acre, while that from the bordeaux mixture and iron sulphate was 235 bushels per acre. The results of the two years taken together would show that in its effect on the plant, the bordeaux in which part of the copper is replaced by iron has as great a stimulating effect as does the ordinary bordeaux. Whether it is as good a fungicide has not yet been proved.

The increased yields from plots where the bordeaux mixture was applied only to part of each plant indicates that even here there was a sufficient effect produced to manifest itself in a yield of 28 bushels per acre more than that obtained on the plots left entirely untreated. This is about what would be expected if half the leaves were touched by the bordeaux.

TWENTY YEARS' SPRAYING FOR POTATO DISEASES

In view of the fact that 1910 marked the close of twenty seasons of experimental spraying against potato diseases at this Station, as well as the departure of all the men hitherto engaged in this line of work, it has seemed desirable to summarize the results that have been obtained during this period in such a form that they may be available to any who may be interested therein, especially since most of the earlier reports and bulletins detailing these results are now out of print. And this despite the fact that bulletin 72 was issued in 1899 which reviewed the situation to date; and that in the resumé report of 1907 which marked the close of twenty years of station existence, the matter was written up to that date, albeit in extremely condensed form.¹ There seems ample reason now, however, for making one more general publication and of closing the chapter for good and all so far as the type of trial thus far carried out is concerned. Those who have similar potato diseases to combat may find it worth while to become acquainted with the success or failure of the many attempts made against these maladies as achieved here; and it is the purpose of this bulletin to set forth these facts in as convenient form as may be for such ready reference.

Beginning with 1891 the experimental trials were conducted under the general direction of Prof. L. R. Jones, the then station botanist, save that last year's (1910) trials were made by the writer. During this time several assistant botanists contributed to the success of the trials, more particularly C. E. Stevens, the late C. C. Tracy, A. J. Grout, W. A. Orton, the

¹Vt. Sta. Rpt. 20, pp. 389-402 (1907); also Bul. 136, pp. 195-199 (1907).

late A. W. Edson, W. J. Morse, N. J. Giddings, and the writer. Starting with the protection of the plants against the late blight by means of sprays, other problems, such as the best spray mixture to use, protection against early blight, effect of the spray mixture on insect injury and on the plant itself, have arisen.

The first statement touching late blight of the potato, made in the publications of this Station was issued in 1888,¹ although it had undoubtedly been present and destructive in Vermont fields many years before.

The blight was again prevalent in 1889.² Bordeaux mixture had been recently suggested by the United States Department of Agriculture as a fungicide for use against the downy mildew and black rot of the grape. Thinking that it might be of service also against the late blight of the potato, some attempts were made late in the season, after the disease had a good start, to use it on the potato vines. The mixture was made according to the following formula: Copper sulphate 4 pounds, dissolved in 16 gallons of water; lime 4 pounds, dissolved in 16 gallons of water. The solutions were mixed and allowed to stand two days before application. Part of a small field was sprayed once with this mixture and part twice. The latter section remained green much longer than did the former. The results were on the whole so favorable that it was resolved to give the mixture a thorough trial the following season.

Experiments were undertaken in 1890³ to determine the effect of one and two sprayings and the relative resistance to rot of about 200 varieties of potatoes at that time in cultivation on the station farm. The bordeaux mixture used was formulated as follows: Six pounds copper sulphate dissolved in 8-10 gallons of water; 4 pounds lime slaked and diluted with water to form a thin paste. The lime poured into the copper sulphate solution and the mixture diluted to 22 gallons.

¹ Vt. Sta. Rpt. 2, p. 121 (1888).

² Vt. Sta. Newspaper Bul. 2 (1889); Vt. Sta. Rpt. 3, pp. 117-118 (1889).

³ Vt. Sta. Bul. 24 (1891); Vt. Sta. Rpt. 4, pp. 131-138 (1890).

The acre yields of marketable tubers obtained were: Sprayed twice, 165¼ bushels; sprayed once, 155 bushels; not sprayed, 86 bushels.

The data as to the resistance of the different varieties to rot were inconclusive.

1891. This year is regarded as the first of the 20 years' series, the two previous years' work being really preliminary in their nature. A comparative test of four fungicidal compounds was made:¹

- (1) Stronger bordeaux mixture (6 pounds copper sulphate, 4 pounds lime, 33 gallons water).
- (2) Ammoniacal copper carbonate (5 ounces copper carbonate, 3 pints ammonia, 45 gallons water).
- (3) Glue mixture (12 ounces sodium carbonate, 10 ounces copper sulphate, 8 ounces liquid glue, 45 gallons water).
- (4) Bordeaux mixture, half strength.

White Star potatoes, a late variety, were sprayed on August 20 and September 8. Both the glue mixture and the ammoniacal copper carbonate seriously injured the leaves. Furthermore they were not as efficient as fungicides as were either the stronger or weaker bordeaux mixtures, of which the stronger proved the better.

The acre yields in bushels were: Sprayed with strong bordeaux mixture, 313; unsprayed, 248; gain, 65.

The presence of a very destructive potato disease—later called "early blight"—was noted for the first time by the station botanist. Many fields were devastated from it by mid-August and all were dead by September 1.

1892. The chief problem was a test of twelve promising fungicides,² including three strengths of bordeaux mixture. They were as follows:

- (1) Copper-soda solution (8 pounds copper sulphate, 12½ pounds sal soda, 50 gallons water).
- (2) Verdigris solution (5 pounds verdigris, 50 gallons water, reduced one-half after first application).
- (3) Bordeaux mixture and molasses (8 pounds copper sulphate, 8 pounds lime, 8 pounds molasses, 50 gallons water).

¹ Vt. Sta. Bul. 28 (1891); Vt. Sta. Rpt. 5, pp. 129-132 (1891).

² Vt. Sta. Rpt. 6, pp. 57-70 (1892).

- (4) Ammoniacal copper carbonate (5 ounces copper carbonate, 3 pints strong ammonia, 45 gallons water).
- (5) Copper and ammonium carbonate (1 pound copper carbonate, 2 pounds ammonium carbonate, 50 gallons water).
- (6) Glue mixture (10 ounces copper sulphate, 12 ounces sal soda, 8 ounces liquid glue, 25 gallons water).
- (7) Modified eau celeste (4 pounds copper sulphate, 5 pounds sal soda, 3 pints ammonia, 45 gallons water).
- (8) Copper carbonate in suspension (1 pound copper carbonate precipitated, 25 gallons water).
- (9) Copper chlorid (3 ounces copper chlorid, 22 gallons water).
- (10) Strong bordeaux mixture (6 pounds copper sulphate, 4 pounds lime, 22 gallons water).
- (11) Weak bordeaux mixture (5 pounds copper sulphate, 5 pounds lime, 50 gallons water).
- (12) Very weak bordeaux mixture (1 pound copper sulphate, 1 pound lime, 30 gallons water).

White Star, a late potato, was used and the mixtures applied July 30, August 13 and August 25.

The late blight was highly destructive, appearing early and causing much tuber rot later, hence an excellent opportunity was afforded of testing the comparative efficiencies of the several fungicides. Strong bordeaux mixture, bordeaux and molasses, weak bordeaux mixture and modified eau celeste were the only sprays whose merit recommended them for practical use. The other eight sprays were beneficial, but did not rank therewith. The acre yields in bushels were: Strong bordeaux mixture, 291 bushels; weak bordeaux mixture, 164 bushels; bordeaux mixture with molasses, 354 bushels; modified eau celeste, 291 bushels; unsprayed, 99 bushels.

The addition of the molasses to the bordeaux increased its fungicidal value, but since it was thought that it might prove a source of danger to bees, its use was not recommended.

A supplemental experiment was made, spraying twice and three times, with the following results per acre:

	Sprayed twice	Sprayed three times
Strong bordeaux mixture.....	157 bushels	291 bushels
Bordeaux mixture and molasses.....	265 bushels	354 bushels
Ammonium copper carbonate	86 bushels	105 bushels

The ravages of the potato disease noted the year before were still worse in 1892. Its careful study led to its being named

"early blight," despite the fact that it sometimes occurs late in the season. The fungus *Macrosporium solani*¹ was found generally associated with the spots and was believed to be the cause, although no inoculation experiments were made.²

1893. The trials for this year³ were designed to determine:

(1) Whether spraying early potatoes was profitable; (2) the best all-round potato fungicide. Twenty-two fungicides were tested as follows:

- (1) Strong bordeaux mixture (6 pounds copper sulphate, 4 pounds lime, 22 gallons water).
- (2) Strong bordeaux mixture plus soap (Babbitt's) at the rate of 1 pound soap to 8 gallons of mixture.
- (3) Weak bordeaux mixture (1 pound copper sulphate, 1 pound lime, 10 gallons water).
- (4) Weak bordeaux mixture plus 1 pound soap to 8 gallons mixture.
- (5) Weak bordeaux mixture plus 1 pound soap to 16 gallons mixture.
- (6) Weak bordeaux mixture plus molasses, 1 pound in 10 gallons mixture.
- (7) Very weak bordeaux mixture (1 pound copper sulphate, 1 pound lime, 20 gallons water).
- (8) Very weak bordeaux mixture, plus 1 pound soap to 8 gallons mixture.
- (9) Very weak bordeaux mixture, plus 1 pound soap to 16 gallons mixture.
- (10) Very weak bordeaux mixture, plus 1 pound soap to 32 gallons mixture.
- (11) Ammoniacal copper carbonate, (5 ounces copper carbonate, 3 pints ammonia, 45 gallons water).
- (12) Ammoniacal copper carbonate, plus 1 pound soap to 16 gallons of the solution.
- (13) Copper and ammonium carbonates (1 pound copper carbonate, 2.2 pounds ammonium carbonate, 50 gallons water).
- (14) Copper and ammonium carbonates, plus 1 pound soap to 16 gallons of solution.
- (15) Modified eau celeste (4 pounds copper sulphate, 5 pounds sal soda, 3 pints strong ammonia, 45 gallons water).
- (16) Modified eau celeste, plus 1 pound soap to 16 gallons of the solution.
- (17) Modified eau celeste, plus 1 pound soap to 32 gallons of the solution.
- (18) Sulpho-steatite, heavy application.
- (19) Sulpho-steatite, lighter application.
- (20) Copper sulphate (1 ounce in 100 gallons water).
- (21) Copper sulphate (8 ounces in 100 gallons water).

¹That the fungus should be called *Alternaria solani* was proved later; (Vt. Sta. Rpt. 9, 79-87, 1895).

²The causal relation of the fungus to the malady was later determined by inoculation (*loc cit.*).

³Vt. Sta. Bul. 40 (1893); Vt. Sta. Rpt. 7, pp. 40-60 (1893).

- (22) Copper sulphate solution (No. 20), plus 1 pound soap to 16 gallons.
 (23) Copper sulphate ($2\frac{1}{2}$ pounds in 100 gallons water), plus 1 pound soap to 8 gallons.

The late blight was not very destructive, but there was much rot of the tubers in the field.

Spraying early varieties.—Early Rose and Polaris were used. The results stated as bushels per acre may be summarized as follows:

Polaris.—Sprayed three times (bordeaux), 254; unsprayed, 170.

Early Rose.—Sprayed 2 times (bordeaux), $246\frac{1}{2}$; unsprayed, $111\frac{1}{2}$.

The stronger bordeaux mixture was found to be the most effective fungicide on the early varieties, but the weaker mixture proved to be nearly as effective.

Spraying late varieties.—White Star was sprayed three times. The gain from spraying the late potatoes was greater than that from spraying earlier ones. Stated as bushels per acre it was: Sprayed 3 times (strong bordeaux), 338; unsprayed, 114.

In all cases the strong bordeaux mixture proved the best fungicide, with the weak mixture a close second. Modified eau celeste was the only other fungicide of practical value and it did not afford as satisfactory results. A few others had slight value.

The leaves sprayed with bordeaux mixtures showed a much smaller number of flea beetle punctures than did those left unsprayed. The sprays were more or less deterrent to the flea beetle. The relative numbers under different treatment are:

Check 2400 holes.

Very weak bordeaux mixture, 1794 holes.

Ammoniacal copper carbonate, 1587 holes.

Modified eau celeste, 1376 holes.

Weak bordeaux mixture, 1298 holes.

Strong bordeaux mixture, 1194 holes.

Bordeaux mixture and soap, 945 holes.

1894. The trials¹ were designed to test the relative values of several fungicides:

- (1) Stronger bordeaux mixture (6 pounds copper sulphate, 4 pounds lime, 22 gallons water).
- (2) Weak bordeaux mixture (5 pounds lime, 5 pounds copper sulphate, 50 gallons water).
- (3) Bordeaux mixture in the form of a powder. (A commercial powder sold under the name of "Fungiroid" was tried; also a similar home-made powder, prepared by drying and grinding the bordeaux mixture precipitate).
- (4) Old bordeaux mixture (prepared in June and used in July and August).
- (5) Bordeaux mixture made by the potassium ferrocyanide test (both strong and weak mixtures were used).
- (6) Modified eau celeste (4 pounds copper sulphate, 5 pounds sal soda, 3 pints strong ammonia, 45 gallons of water).
- (7) Ammoniacal copper carbonate, Delaware formula: (5 ounces copper carbonate, 3 pints strong ammonia, 45 gallons of water).
- (8) Fungicides plus soap. Soap was added to the following mixtures: Strong bordeaux mixture made up according to potassium ferrocyanide test, modified eau celeste, ammoniacal copper carbonate.

The year was an unfavorable one for testing the fungicidal value of these mixtures, as the summer months were the driest in years. No disease appeared and any differences shown in the results are due to protection against insects combined with the physiological effect of the fungicides on the potato plant itself.

White Star, Polaris and Early Rose potatoes were planted. Applications were made on June 30, July 18, and August 30. The comparable results are as follows:

Stronger bordeaux mixture	260 bushels per acre
Weak bordeaux mixture	256 bushels per acre
Bordeaux powder	243 bushels per acre
Old bordeaux mixture	229 bushels per acre
Strong bordeaux mixture, ferrocyanide test.....	241 bushels per acre
Weak bordeaux mixture, ferrocyanide test.....	242 bushels per acre
Modified eau celeste	240 bushels per acre
Ammoniacal copper carbonate	163 bushels per acre
Check row, untreated	162 bushels per acre

The above figures are averages. The gains were somewhat different from the use of bordeaux mixture on White Star potatoes alone: 323 bushels per acre from the sprayed, 251 bushels per acre from the unsprayed.

¹ Vt. Sta. Bul. 44 (1895); Vt. Sta. Rpt. 8, pp. 93-104 (1894).

The addition of the soap was found to be of no avail and the ammoniacal copper carbonate was proved unadapted to this purpose. It was developed, moreover, that old mixtures seemed to lose considerable of their effects on account of aging.

The dry weather favored the attacks of the flea beetle. The average number of holes per leaflet in the unsprayed row were found by counting to be 262, while the sprayed row averages were 12.

1895. The previous years' results had clearly shown bordeaux mixture to be the best potato fungicide. Certain forms of the mixture were found to be more convenient to apply than were others, but there was reason to question whether they were of equal value to the properly prepared fresh mixture. The following forms of these more convenient preparations were used in this year's¹ tests for comparison with the ordinary mixture:

- (1) Standard bordeaux mixture ($7\frac{1}{2}$ pounds of copper sulphate, 5 pounds of lime, 50 gallons of water).
- (2) Test bordeaux mixture ($7\frac{1}{2}$ pounds of copper sulphate in 50 gallons of water with enough lime, as shown by the potassium ferrocyanide test, to neutralize the copper sulphate).
- (3) Stock bordeaux mixture (prepared early in the season according to standard formula but with only half the required amount of water, diluted to required amount of water just before application).
- (4) Bordeaux powder made from standard bordeaux mixture. Applied in three ways: (a) dry and undiluted; (b) dry after dilution with three times as much flour; (c) wet after dilution with four times as much water.
- (5) "Fungiroid." A commercial powder applied: (a) dry and undiluted; (b) dry after dilution with three parts of flour.

Each of these fungicides was applied three times: July 25, August 13, August 31. The late blight was serious from the first of September onwards and the tuber rot was widespread. The results obtained, expressed in yields per acre, were as follows:

¹ Vt. Sta. Bul. 49 (1895); Vt. Sta. Rpt. 9, pp. 93-98 (1895).

Treatment	Large sound tubers	Large rotten tubers
Standard bordeaux mixture	389 bushels	67 bushels
Test bordeaux mixture	349 bushels	78 bushels
Stock bordeaux mixture	322 bushels	112 bushels
Bordeaux powder, dry, undiluted.....	235 bushels	182 bushels
Fungiroid, dry, undiluted	220 bushels	156 bushels
Check, no fungicide	219 bushels	168 bushels

The stock bordeaux, bordeaux powder, and Fungiroid were practically valueless, and the powdered bordeaux when diluted with flour entirely so.

Studies of the early blight were made this year and it was shown to be due to a fungus, *Alternaria solani*, known previously as *Macrosporium solani*. Inoculation experiments proved that this fungus would produce typical spots of the disease on potato leaves.

1896. Three variations of bordeaux mixture were tried:¹

- (1) Standard bordeaux mixture (7½ pounds copper sulphate, 5 pounds lime, 50 gallons water).
- (2) Half-lime bordeaux mixture (7½ pounds copper sulphate, 2½ pounds lime, 50 gallons water).
- (3) Bordeaux powder (the precipitate of standard bordeaux mixture dried and ground. Applied with a "powder gun").

Polaris potatoes were sprayed twice, August 7, August 21, with the above mixtures. No late blight or rot occurred. The results indicate that the half-lime bordeaux was as good as the standard but not as safe to use. The bordeaux powder seemed to be valueless.

1897. No extensive comparative trials of fungicides were made.² Previous experience had shown the bordeaux mixture to be so superior that a continuation of such trials was deemed to be of but little value. Part of one field was sprayed twice with standard bordeaux mixture and part of another field was sprayed three times: July 27, August 17 and 28. The results stated as bushels per acre were: Sprayed twice with bordeaux mixture,

¹Vt. Sta. Rpt. 10, pp. 52-53 (1896).

²Vt. Sta. Rpt. 11, pp. 190-192 (1897).

124; unsprayed check, 90; sprayed three times with bordeaux mixture, 151; unsprayed check, 80.

1898. Tests were made of three forms of bordeaux mixture:¹

- (1) Standard bordeaux mixture (7½ pounds copper sulphate, 5 pounds lime, 50 gallons water). The copper sulphate was dissolved in 25 gallons of water, and the two poured together.
- (2) Improperly made bordeaux mixture. (The concentrated lime water [1 pound to the gallon] was added to the concentrated copper sulphate solution [1 pound to the gallon] and then diluted to 50 gallons).
- (3) Commercial bordeaux mixture. (A commercial concentrated mixture called the "Lion Brand" was diluted according to directions and the same quantity used as of the other two mixtures).

The season was a dry one. Great damage was done by tip-burn and insect injuries, but little blight occurred. The efficacy of these mixtures as fungicides was therefore not determined. The results were as follows, stated as average yield in bushels per acre:

Fungicide	Dates of application	Marketable tubers	Small tubers
Standard bordeaux mixture,	July 21, Aug. 9, Sept. 9,	239	28
Improperly made bordeaux mixture,	July 21, Aug. 9, Sept. 9,	230	28
Standard bordeaux mixture,	Aug. 9, Sept. 9,	186	20
Commercial bordeaux mixture,	Aug. 9, Sept. 9,	159	34
Check, no fungicide,		112	42

These results indicate that the improperly made bordeaux mixture had nearly as much effect on the plants as had the regularly made mixture. However, it adhered to the foliage less tenaciously and was troublesome on account of clogging the spray nozzle.

The same objections were found with the commercial bordeaux mixture. Furthermore it was found to be expensive, the cost being about 3 cents a gallon, while the home made mixture only cost about 1 cent a gallon.

Two commercial insecticides, bug death and laurel green, were tried but were found to be inferior to the bordeaux mixture containing paris green as preventives of insect injuries.

¹Vt. Sta. Rpt. 12, pp. 151-156 (1899).

1899. The spraying experiments¹ were tests: (1) Of various insecticides; (2) Of the gain from spraying at different dates.

The standard bordeaux mixture, such as had been used in previous years (7½ pounds copper sulphate, 5 pounds lime, 10 ounces paris green, 50 gallons water) was used as a check on the insecticidal efficiency of paris green mixed with gypsum, and two commercial insecticides, laurel green and bug death. The mixtures were applied July 26, August 17, and September 8. There was little damage done the crop save by insects and tip-burn.

The results are as follows, expressed as yield in bushels per acre:

Nature of application	White Star	Rural New Yorker	Average
Bordeaux-paris green mixture,	227	237	232
Check, paris green in water,	166	168	167
Gypsum-paris green mixture,	179	189	184
Laurel green, 1 pound per acre,	141	197	169
Laurel green, 2 pounds per acre,	151	181	166
Bug death, 3 pounds per acre,	217	190	203
Bug death, 5 pounds per acre,	187	201	194

The efficiency of the bordeaux-paris green mixture was marked. Bug death was shown to have value, but to be prohibitively costly in the amount in which it would have to be applied in field practice entirely to prevent insect injury.

The results from spraying at different dates, expressed as bushels per acre, were:

July 26, August 17, September 8	227 bushels
July 26, August 17	193 bushels
July 26, September 8	203 bushels
July 26	185 bushels
August 17, September 8	150 bushels
August 17	152 bushels
Check, not sprayed	134 bushels

The first application was the most important one, and about one-half the gain was attributable thereto.

¹ Vt. Sta. Rpt. 13, pp. 268-273 (1900).

1900. The tests¹ were made along the same line as those of 1899, viz.:

- (1) Of certain commercial insecticides and fungicides.
- (2) Of the relative values of applications of bordeaux mixture at different dates. Boxal, a commercial insecticide and fungicide combined, and Bodo, a concentrated commercial fungicide designed to take the place of bordeaux mixture, were the commercial mixtures used. Applications were made July 12, August 4 and 23. Neither the early nor the late blights were prevalent, although they were present. The insect damage was serious.

The yields per acre in bushels were: Bordeaux-paris green mixture, 285; control, 224; Bodo, 232. Boxal was not used early enough to compare. The acre yields, when plots were sprayed at different dates, were:

Control, paris green alone	225 bushels
Bordeaux mixture, July 2, July 17	227 bushels
Bordeaux mixture, July 2, July 17, August 4	240 bushels
Bordeaux mixture, July 2, July 17, August 4 and 23	286 bushels
Bordeaux mixture, August 4	234 bushels
Bordeaux mixture, August 4, August 23	285 bushels
Bordeaux mixture, August 23	267 bushels

1901. The experiments² were intended to compare dusting the plants with paris green alone with:

- (1) Bordeaux-paris green mixture, applied once.
- (2) Bordeaux-paris green mixture, applied twice.
- (3) Bug death, a commercial powder claiming to be both a fungicide and an insecticide.

Delaware potatoes were planted. Applications of bordeaux and bug death were made on July 20 and August 23, the bug death being used at the rate of 25 pounds and of 62 pounds per acre. Another plot was sprayed with the bordeaux-paris green mixture on July 20 and part of it a second time on August 24. The ravages of blight and rot were severe, affording an admirable opportunity for testing the fungicidal efficiency of the applications.

¹ Vt. Sta. Rpt. 14, pp. 227-231 (1901).

² Vt. Sta. Rpt. 15, pp. 209-215 (1902).

The results stated as yield of potatoes of marketable size in bushels per acre were:

Treatment	Sound	Rotten	Total	Percent rotten
Bug death in water, 25 pounds,	63	131	194	67
Bug death dry, 62 pounds,	66	112	178	63
Bordeaux-paris green mixture,	151	71	252	32
Bordeaux-paris green mixture, July 20, August 24,	170	13.5	183.5	7
Bordeaux-paris green mixture, July 20,	54.3	79.5	133.8	60.

The second spraying prolonged the life of the vines, checked the rot and added 66 bushels to the yield.

1902. Delaware potatoes¹ were sprayed two and three times for comparison with unsprayed plots of the same variety. The standard bordeaux mixture ($7\frac{1}{2}$ pounds copper sulphate, 5 pounds lime, 50 gallons water) was used. The late blight and the resulting rot were prevalent and destructive.

The results stated as bushels per acre were:

	Sound	Rotten	Total
Not sprayed,	164	34	198
Sprayed twice,	298	47	345
Sprayed three times,	311	11	322

The infection of the tubers from the late blight resulting in the wet rot is brought about by the spores falling on the ground, working their way through the protecting layer of soil. Hence spraying the soil to kill the spores when they fell on the ground was tried. The branches of the plants on a small area were raised and a spray was directed on August 13 underneath so as to wet the surface of the soil while avoiding the foliage as far as possible; those on a second area were not sprayed in any way; and the tops of those on a third area were sprayed as usual on August 13 and on September 6. The results were as follows in pounds for the three rows used in each treatment:

¹ Vt. Sta. Rpt. 15, pp. 215-219 (1902).

	Sound	Rotten
Soil sprayed,	151	2.5
Not sprayed,	113	26.
Vines sprayed,	182	25.5

There were irregularities in the soil on which the plots were located which made the above results not at all conclusive. Soil spraying is not recommended as a practical remedy; however, it did seem to reduce the rot somewhat.

1903. On one plot,¹ half the rows of Green Mountain potatoes were thoroughly sprayed on August 10 with the standard bordeaux-paris green mixture. The alternating rows were left unsprayed. Late blight did not appear until comparatively late in the season and the one spraying was adequate protection, although blight and rot became abundant.

The yields in bushels per acre were as follows:

	Sound tubers	Rotten tubers	Percent rotten
Sprayed,	361	31	8
Unsprayed,	237	48	17

On another plot, bug death and paris green were added to the bordeaux mixture in order to compare the results when so applied, with those obtained when they were used alone. The loss in the yield was largely due to the late blight of the foliage. The trials of the two years preceding showed that while bug death had value in checking insect ravages it was not effective against the late blight. The following table gives the treatment and the yield from each treatment (three rows) in pounds:

Treatment	Yield (3 rows)
Paris green in water	220 pounds
Control (untreated)	241 pounds
Bordeaux-paris green mixture	278 pounds
Bordeaux-bug death mixture	280 pounds
Bug death, applied dry	237 pounds

¹ Vt. Sta. Rpt. 16, pp. 155-161 (1903); also Bul. 106, pp. 230-232 (1903).

1904. The tests¹ were simply a continuation of the determination of the efficacy of standard bordeaux mixture. Delaware potatoes on two plots and an unknown variety on a third plot were sprayed twice, control rows being left in each case. Late blight did not appear until September, but spread rapidly during that month, owing to the very rainy weather. It caused great loss from rot, one field being hardly worth digging.

The yields stated as bushels per acre were:

	Total yield		Increase	Rotten	Net gain	
	Sprayed	Un-sprayed		Sprayed	Un-sprayed	
Field 1, July 26, Aug. 25,	294	234	60	¼	30	90
Field 2, Aug. 5, Sept. 1,	370	368	2	0	48	50
Field 3, Aug. 5, Sept. 5,	344	301	43	27	245	261
Average,	336	301	35	9	108	134

1905. The spraying work was directed along the following lines:²

- (1) Demonstration of the value of spraying with bordeaux mixture over not spraying at all.
- (2) Spraying the soil to prevent the rot.
- (3) Spraying as a remedy for early blight.

Bordeaux mixture, consisting of 6 pounds of copper sulphate, 4 pounds of lime and 40 gallons of water with ½ pound of paris green, was applied August 2 and August 21 to Delaware potatoes. The late blight destroyed the tops of the plants that had been left unsprayed as controls, early in September. The results in the bushels per acre were as follows:

	Sound tubers	Rotten tubers
Sprayed,	382 bushels	6 bushels
Unsprayed,	221 bushels	56 bushels

Eight rows of Delaware potatoes planted in heavy, moist clay loam, a soil especially favorable to rot, were used in testing

¹ Vt. Sta. Rpt. 17, pp. 386-391 (1904); also Bul. 111, pp. 27-30 (1904).

² Vt. Sta. Rpt. 18, pp. 272-277 (1905); also Bul. 119, pp. 21-26 (1905).

the effect of spraying on the soil. The soil under the plants on four of these rows was carefully sprayed with bordeaux mixture on August 2, August 18 and August 28, care being taken that none of it fell on the foliage. The plants on the other four rows were entirely untreated. As noted above, the blight and rot were bad in September, thus affording ideal conditions for the test. The yield from the four rows was as follows:

	Sound tubers	Rotten tubers	Percent rotten
Four rows, soil sprayed,	60.2	12.5	17
Four rows, untreated,	13.5	57.9	81

While soil spraying was not recommended in practice, it was noted that in the later sprayings when the disease is bad and the soil heavy, it might pay to make extra heavy applications of the mixture in order that enough may reach the surface of the soil to check the development of the fungus spores falling thereon.

Early blight was very abundant on one field and spraying trials were made against it. There were thirty-six rows of potatoes used, each 60 feet long, consisting of six rows each of the following varieties: Rural New Yorker No. 2, Delaware, Green Mountain, Polaris, Early Rose, and Early Ohio. On August 28 the extent of the damage to the foliage on the unsprayed plots was estimated as follows:

DAMAGE FROM EARLY BLIGHT ON UNSPRAYED PLANTS

Variety	Foliage killed	Variety	Foliage killed
Rural New Yorker No. 2,	15 percent	Polaris	50 percent
Delaware,	25 percent	Early Rose	75 percent
Green Mountain,	50 percent	Early Ohio	90 percent

Two rows of each variety were left unsprayed, but were dusted with paris green and lime; two rows were sprayed with the bordeaux mixture (6 pounds copper sulphate, 4 pounds lime, 40 gallons water, $\frac{1}{2}$ pound paris green) five times, July 15 and 24, August 2, 18 and 28; two rows were sprayed with the same mixture on July 15, August 2 and August 24.

The following are the yields in bushels per acre:

	Sprayed 5 times	Sprayed 3 times	Not sprayed
Rural New Yorker No. 2,	242	298	222
Delaware,	237	210	93
Green Mountain,	218	198	89
Polaris,	161	169	109
Early Rose,	258	169	48
Early Ohio,	218	230	121
Average,	222	188	114

These results emphasized the beneficial effects of spraying every variety of potato. Five applications are shown to be slightly better than three, but not enough so to make the extra two of much practical consequence.

1906. There were two objects in mind in the 1906 trials:¹

(1) To continue the demonstration of the practical results of spraying with bordeaux mixture.

(2) To compare the results attained by the use of paris green and lime with those obtained using three commercial compounds: "Copper phosphate," "Dust Bordeaux" and "1-2-3."

(1) A sand loam and a heavy clay loam were used, and Green Mountain potatoes were planted. Bordeaux mixture (5-5-50 formula with $\frac{1}{2}$ pound of paris green added) was applied at the average rate of 130 gallons per acre, twice on the sandy loam, August 13 and August 22, while four applications were made on the clay loam, July 18 and 27, August 8 and 22. The control rows were dusted with paris green and lime (1-20). No late and but very little early blight was present.

The results stated as bushels per acre on the sandy and clay soils were those shown in the table on the top of the next page:

¹ Vt. Sta. Rpt. 19, pp. 265-269 (1906); also Bul. 129, pp. 104-108 (1906).

	Total yield	Marketable tubers	Small tubers
Bordeaux mixture and paris green,	473	411	62
Control, paris green and lime,	371	312	59
Gain from bordeaux mixture,	102	99	3
Bordeaux mixture and paris green,	336	214	117
Control, paris green and lime,	189	128	61
Gain from use of bordeaux mixture,	142	86	56

(2) Four plots were used in this experiment:

- (1) Copper phosphate (fungicide only), applied 13 pounds per acre.
- (2) Dust bordeaux (fungicide only), applied 17 pounds per acre.
- (3) 1-2-3 (fungicide and insecticide), applied 10 pounds per acre.
- (4) Paris green and lime.

The copper phosphate, dust bordeaux and 1-2-3 were applied dry over half of the plot while the plants were wet with dew, while on the other half they were mixed with water (1 pound to 5 gallons of water) before application. Paris green (1½ pounds per acre) was added to the copper phosphate and dust bordeaux.

The yields in pounds from the plots were as follows:

	Total yield	Large tubers	Small tubers
Copper phosphate,	198	141	57
Dust bordeaux,	216	151	65
1-2-3,	216	163	53
Paris green and lime,	210	165	45

No late blight was present, so no opportunity was given of testing their fungicidal value. The 1-2-3 seemed to be a reliable insecticide, however, and all the compounds showed the tonic effect on the potato foliage characteristic of the bordeaux mixtures.

1907. The spraying experiments of 1907¹ were designed to show:

¹ Vt. Sta. Rpt. 20, pp. 334-342 (1907); also Bul. 136, pp. 190-195 (1907).

(1) The gain from spraying with bordeaux-paris green and the comparative merits of two, three and of four applications.

(2) The gains from commercial compounds (boxal and bug death) as compared with bordeaux mixture and paris green.

(1) The standard bordeaux mixture (5-5-50) used together with $\frac{1}{2}$ pound paris green. Green Mountain potatoes were sprayed as follows:

- Plot I. Bordeaux applied four times, July 16 and 25, Aug. 8 and 22.
 Plot II. Bordeaux three times, July 28, Aug. 8 and 22.
 Plot III. Bordeaux two times, Aug. 8 and 22.
 Plot IV. Control, dusted with paris green in lime.

Early blight was destructive, but no late blight or rot was observed. The results per plot were as follows:

	Large tubers pounds	Small tubers pounds	Total yield pounds	Gain in marketable tubers over check pounds percent	
Plot I. Sprayed four times,	191.9	46.0	237.9	97.1	69
Plot II. Sprayed three times,	144.2	51.9	196.1	41.8	29
Plot III. Sprayed two times,	154.3	51.8	206.1	31.8	22
Plot IV. Check, paris green,	82.6	58.2	140.8		

On September 6 typical plants were examined for early blight and for flea beetle punctures with the following results:

	Leaflets badly eaten by flea beetle	Leaflets badly diseased with early blight
Bordeaux four times, July 16, 25, Aug. 8, 22,	48%	40%
Bordeaux three times, July 25, Aug. 8, 22,	55%	45%
Bordeaux twice, Aug. 8, 22,	95%	75%
Paris green in lime,	97%	80%

(2) Ten rows were used in a comparative trial of boxal, bug death and bordeaux-paris green mixture.

- I. Two rows bordeaux mixture (5-5-50, with $\frac{1}{2}$ pound paris green), applied five times, 150-200 gallons to the acre.
- II. Two rows, boxal (mixed with water, one pound to 10 gallons), applied five times at the rate of 19 pounds to the acre.

- III. Two rows, bug death (mixed with water, one pound to 10 gallons), applied five times at the rate of 25 pounds to the acre.
 IV. Four rows, control dusted with paris green mixed with lime, 1 to 20, at the rate of 30 pounds per acre.

On September 6, leaflet counts from the four plots showed the relative damage from the flea beetle and early blight to be as follows:

Treatment	Leaflets badly punctured by flea beetle	Leaflets badly diseased by early blight
Bug death,	52%	47%
Boxal,	60%	60%
Bordeaux,	37%	32%
Paris green and lime,	95%	88%

On September 30, a count was made of the plants still showing living leaves with the following results:

Bug death	17 percent of plants alive
Boxal	4 percent of plants alive
Bordeaux	68 percent of plants alive
Check (paris green)	0 percent of plants alive

The yields from the various plots on October 11 were as follows:

AVERAGE YIELD OF TUBERS OF MARKETABLE SIZE

	Yield of large tubers	Gain over check
Boxal,	144.1 pounds	50.5 pounds or 54 %
Bug death,	127.0 pounds	33.4 pounds or 35.6%
Bordeaux-arsenic,	166.5 pounds	72.9 pounds or 77.9%
Check (paris green),	93.6 pounds	

From the above tables it will be seen that while both bug death and Boxal have insecticidal and fungicidal value, they are less effective than is the freshly prepared bordeaux-arsenical mixture; and they are more costly.

1908. Lime-sulphur mixture was used for comparison with the bordeaux mixture.¹

¹ Vt. Sta. Bul. 142 (1909).

Bordeaux mixture (5-5-50 formula with one-half pound paris green added) was applied four times to one plot, June 26, July 9, August 5 and 26, and two times to another, August 6 and 26. Lime-sulphur mixture (consisting of 15 pounds of lime in which had been boiled 10 pounds of sulphur, diluted to 50 gallons) was sprayed four times on the same dates as the bordeaux and at the same rate. The control rows were dusted with paris green and lime, 1 to 20.

Two fields were utilized, a sandy loam and a clay loam. But little early blight occurred and no late blight or rot.

Sandy loam, Green Mountain potatoes. Yields in bushels per acre:

Treatment	Large tubers	Small tubers	Total	Gain, percent large tubers
Bordeaux mixture, four times,	145	11	156	154
Bordeaux mixture, two times,	106	11	117	85
Lime-sulphur,	74	13	87	29
Control (paris green),	57	11	68	

Clay loam. Plots 1-3, Irish Cobbler; 4-6, White Star. Yield in bushels per acre:

	Large tubers	Small tubers	Total	Gain, percent large tubers
1 Bordeaux mixture, four times,	76	12	76	128
2 Control (paris green),	37	9	37	...
3 Lime-sulphur, four times,	58	12	58	64
4 Lime-sulphur, four times,	64	16	64	17
5 Control (paris green),	53	12	53	...
6 Bordeaux mixture, two times,	72	11	72	48

While the lime-sulphur mixture was shown to have value by the increase of 37 percent of the sprayed over the control plots, it did not equal the bordeaux mixture in value, for the increase was 67 percent when bordeaux was used twice, and 141 percent when used four times.

1909. As the fungicidal value of bordeaux mixture had been thoroughly demonstrated by the work of the previous years,

the object of the 1909 trials¹ was to determine what constituents of the mixture caused the tonic effect on the potato plant, resulting in an increased yield in years when no diseases except tip-burn were present.

The following applications were made:

- (1) Bordeaux mixture (5-5-50 formula).
- (2) Bordeaux mixture in which part of the copper sulphate had been replaced by iron sulphate (2 pounds copper sulphate, 4 pounds iron sulphate, 6 pounds lime, 50 gallons water).
- (3) Iron sulphate with lime (5 pounds iron sulphate, 5 pounds lime, 50 gallons water).
- (4) Bordeaux mixture of the above proportions sprayed on the soil at the same rate as number 1 was applied to the foliage.
- (5) Control plots, dusted with paris green and lime (1 to 20).

Paris green at the rate of $\frac{1}{2}$ pound to 50 gallons water was used in the first three cases.

Green Mountain potatoes were sprayed July 12 and 23, August 6 and 26. No late or early blight was present and tip-burn was only fairly abundant.

The yields in bushels per acre from the various plots were as follows:

Treatment	Marketable tubers	Small tubers	Total
Bordeaux mixture,	192	51	243
Bordeaux mixture, plus iron sulphate,	184	51	235
Iron sulphate, plus lime,	117	51	168
Bordeaux mixture on soil,	115	75	190
Control (paris green and lime),	138	50	188

The large increase occurred on the first two plots, i. e., those sprayed with mixtures containing copper. It would seem from this that the copper was the stimulating constituent of the bordeaux mixture.

1910. This work has already been presented in this bulletin, pages 219-225, therefore a rediscussion of it at this point is unnecessary.

¹ Vt. Sta. Bul. 153 (1910).

SUMMARY

The results from the work of the twenty years' spraying may be best seen in the form of a table in which only the yields from the plots sprayed with bordeaux mixture are compared with control plots that have been left unsprayed.

GAINS FROM THE USE OF BORDEAUX MIXTURE ON LATE POTATOES.

Planted	Sprayed	Yield per acre		Gain per acre		Prevalence of late blight
		Sprayed	Not sprayed			
White Star,		bu.	bu.	bu.	%	
May —, 1891	Aug. 26, Sept. 8,	313	248	65	26	some
May 20, 1893	Aug. 1, 16, 29,	291	99	192	194	much
May 20, 1893	Aug. 1, 16, 29,	338	114	224	196	much
Apr. 26, 1894	June 16, July 17, Aug. 30,	323	251	72	29	none
May 20, 1895	July 25, Aug. 13, 31,	389	219	170	78	rot
Polaris,						
May 15, 1896	Aug. 7, 21,	325	267	68	26	none
June 1, 1897	July 27, Aug. 17, 28,	151	80	71	89	some
White Star,						
May 10, 1898	July 21, Aug. 10,	238	112	126	112	little
Average,						
3 varieties,						
May 18, 1899	July 26, Aug. 17, Sept. 8,	229	161	68	42	little
Delaware,						
May 23, 1900	Aug. 4, 23,	285	225	60	27	rot
May 25, 1901	July 20, Aug. 21,	170	54	116	215	much
May 15, 1902	Aug. 1, 20,	298	164	134	82	severe
Green Mountain,						
May 1, 1903	Aug. 10,	361	237	124	52	severe
Delaware,						
May 25, 1904	Aug. 1, Sept. 1,	327	193	134	69	some
May 15, 1905	Aug. 2, 21,	382	221	161	73	severe
Green Mountain,						
May 27, 1906	Aug. 13, 22,	133	101	32	32	some
May 1, 1907	July 16, 25, Aug. 8, 22,	171	63	108	175	little
May 15, 1908	June 26, July 9, Aug. 6, 26,	156	65	91	140	none
May 28, 1909	July 12, 23, Aug. 6, 27,	243	188	55	29	none
May 9, 1910	July 11, 27, Aug. 15, 23, 30,	240	202	38	18	none
Average for 20 years,		268	163	105	64	

POTATO DISEASES AND THE WEATHER

Scattered through botanical literature and agricultural journals have appeared numerous references and notes on the effect of local weather conditions on the occurrence and spread of plant diseases in certain regions. Some of these, such as the accounts of the diseases of New Jersey plants, as made by Halsted year after year in the publications of that Station, have discussed the question in detail for the maladies prevalent during each season. He has brought many of these observations together in his interesting paper on "The influence of wet weather upon parasitic fungi."²

Many of the stations in this and foreign countries now publish yearly notes on the occurrence and destructiveness of plant diseases. The United States Department of Agriculture through its plant disease survey is also collecting data that should serve as a basis for broad generalizations on the subject.

No attempt has been made, however, so far as the writer is aware, to correlate the relations of the weather and any one plant malady covering a long period of time. The former station botanist (L. R. Jones)² studied the relation of the weather to the late blight during the five years, 1891-1895, but has not continued the study during the following fifteen years, further than to make records of striking instances of such correlations. The reason for this apparent omission doubtless lies in the fact that, with the exception of this Vermont data, long time observations on the diseases of a single plant are lacking. It must be remembered that our knowledge of fungi, and especially of their relation to plant diseases, is of comparatively recent origin. However, a fairly complete account of the occurrence and spread of potato diseases has been kept at this Station for the past twenty years and recorded in its publications. Many of these are now out of print. They usually record a single season's observations unrelated to those of other years. It would seem worth while to

¹Bul. Torr. Bot. Cl. 26, pp. 380-389 (1899).

²Vt. Sta. Rpt. 9, pp. 66-71 (1895).

bring them together and to relate them to one another for their own value as well as for the reason cited elsewhere. Furthermore, practically complete local weather records are available covering the same period. These were kept by a cooperating observer, Mr. Walter B. Gates, until the establishment of the United States weather station at this institution. The writer's thanks are due to the present observer at Burlington, Mr. J. K. Hooper, for kindly placing at his disposal the necessary meteorological data.

While the relation between weather conditions and the occurrence of the potato disease is not always clear, there are striking instances of such relationship as will be noted later. The dependence of the spread of the disease upon favorable weather conditions is usually clear. It must be remembered, however, that the potato plant is an exotic of comparatively recent introduction in this country, as well as the fact that it has not as yet become fully acclimated to the weather conditions of Vermont, particularly to its short and comparatively dry summers. Whether the fact that it is a stranger among us has so weakened the plant that it has more easily fallen a prey to fungi or to untoward conditions is not certain, but this much at any rate is clear, that the potato plant has its full share of diseases and that these diseases seem to be largely the result of weather conditions which favor the growth of parasitic organisms.

The principal diseases concerning which the records have been kept at the station are:

- (1) Late blight of the potato foliage, produced by the fungus, *Phytophthora infestans*, associated with and following which is the rot of the potato tubers.

- (2) Early blight of the foliage, due to the attacks of the fungus, *Alternaria solani*.

- (3) Tip-burn, a physiological disease, due to the lack of water, manifesting itself in the scorching of the tips on the leaflets.

The term "potato blight" in popular parlance is applied only to the first of these three maladies, but it has been shown that the other two are also "blights," which under certain conditions are highly destructive. The late blight, however, is the disease upon which the fullest records have been kept, as it is the one which is the most to be feared and which economically is most important. Hence the relations the weather bears to the late blight and rot are more particularly under survey in the following study.

In view of the great destructiveness of the malady and of the fundamental importance of the potato in human feeding, the condition under which late blight first originates and spreads should be of interest wherever it occurs, whether in this country or Europe. In order to make as accurate a picture as possible of these conditions favoring or retarding its growth, a series of charts has been prepared and is shown herewith, displaying for each season not only the curve for both the daily maximum and minimum temperatures for the three months in which blight occurs, July, August and September, but also the daily rainfall and the condition of the sky. The record of the humidity of the air would probably also reveal many interesting relationships but the data thereon is not available. The curves representing daily maximum and minimum temperatures and the black lines for the daily rainfall are all clear on the charts. The condition of the day is represented by the following symbols:

Day entirely cloudy, day partly cloudy, day clear.



Late blight was first recorded¹ in the Vermont station reports as appearing destructively in 1889. It had undoubtedly been abundant before this time, however. Halsted² records that in New Jersey "1889 was a remarkable year for the abundance of rain and also for the prevalence of destructive fungi. *Phytoph-*

¹ Vt. Sta. Rpt. 2, p. 121 (1889).

² Bul. Torrey Bot. Club, 26, pp. 380-389 (1899).

thora infestans was so abundant in some fields that scarcely a leaf escaped its attacks. Large growers throughout whole sections of the country did not harvest their potatoes, while others dug and placed them in heaps where they rotted."

The late blight and rot were abundant again in 1890¹, being so destructive that active measures—spraying with bordeaux—were taken against it by the then station horticulturist. Halsted reports that potato rots of various sorts were very destructive in New Jersey and that 1890 "has been a year of trouble with potatoes."

On the following odd numbered pages 253 to 291, the Burlington weather data is presented in the form of charts for July, August and September of each year, from 1891 to 1910, while on the even numbered pages opposite to the charts are given the notes on potato diseases derived from the station publications for the year charted on the opposite page, with an attempt to correlative them as nearly as possible with the facts shown on the chart. As noted before, the chart shows four facts regarding the weather for each day:

- (1) *Upper curve, maximum temperature.*
- (2) *Lower curve, minimum temperature.*
- (3) *Black columns, rainfall; unoccupied area, no rain.*
- (4) *Square at extreme bottom of each chart, amount of sunshine as indicated on opposite page to this note.*

¹Vt. Sta. Rpt. 9, p. 67 (1895).

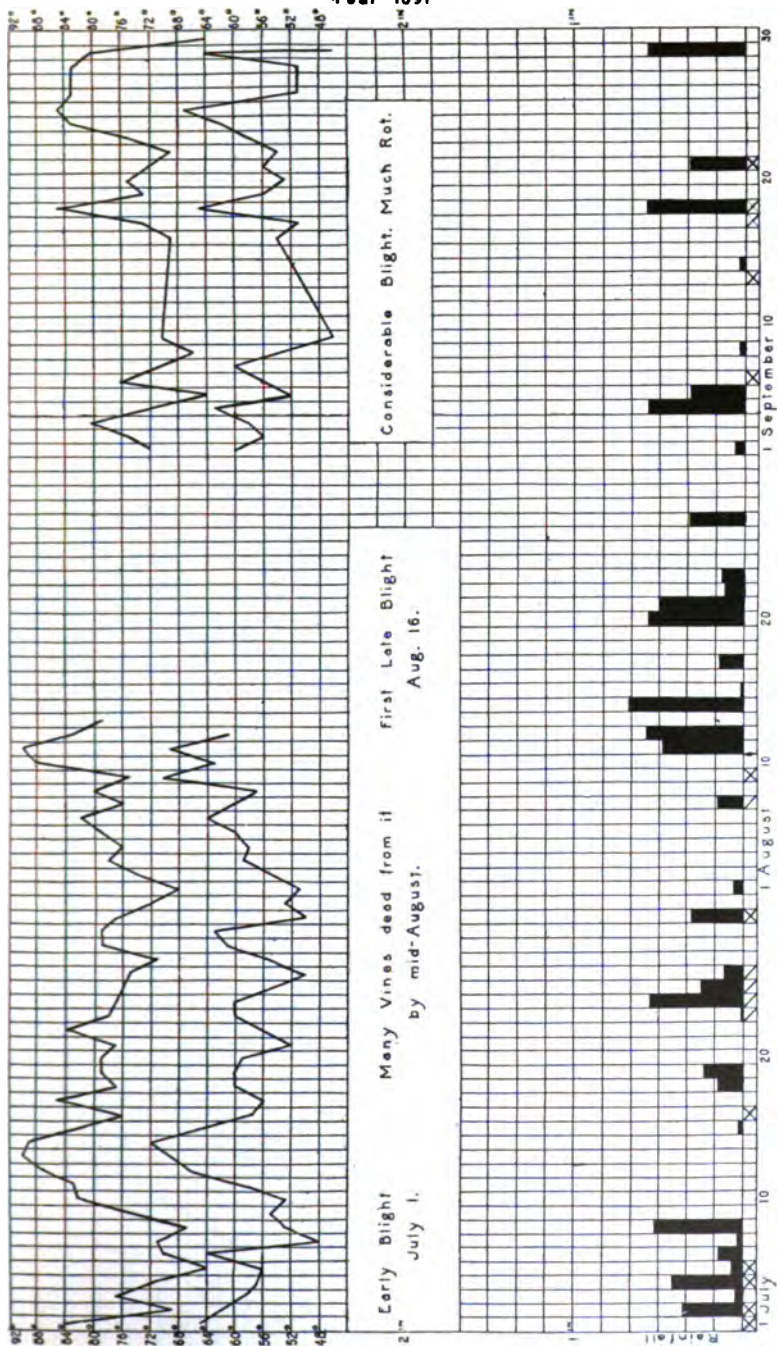
1891. The conditions under which blight appeared are discussed by Jones^a as follows:

"The temperature was low and rainfall slight. The weather became very warm and on the 12th and 14th was followed by a fall in temperature and copious rains, and this is followed by another rise in temperature and more rains about the 21st. The conditions favoring the blight began thus about the 12th. The blight was first observed the 16th or 17th. When it is remembered that such a fungus requires several days in which to get under way before noticeable injury appears, it is seen that the records place the occurrence of the blight at the time when it might be expected."

The temperature data for this year are not quite complete.

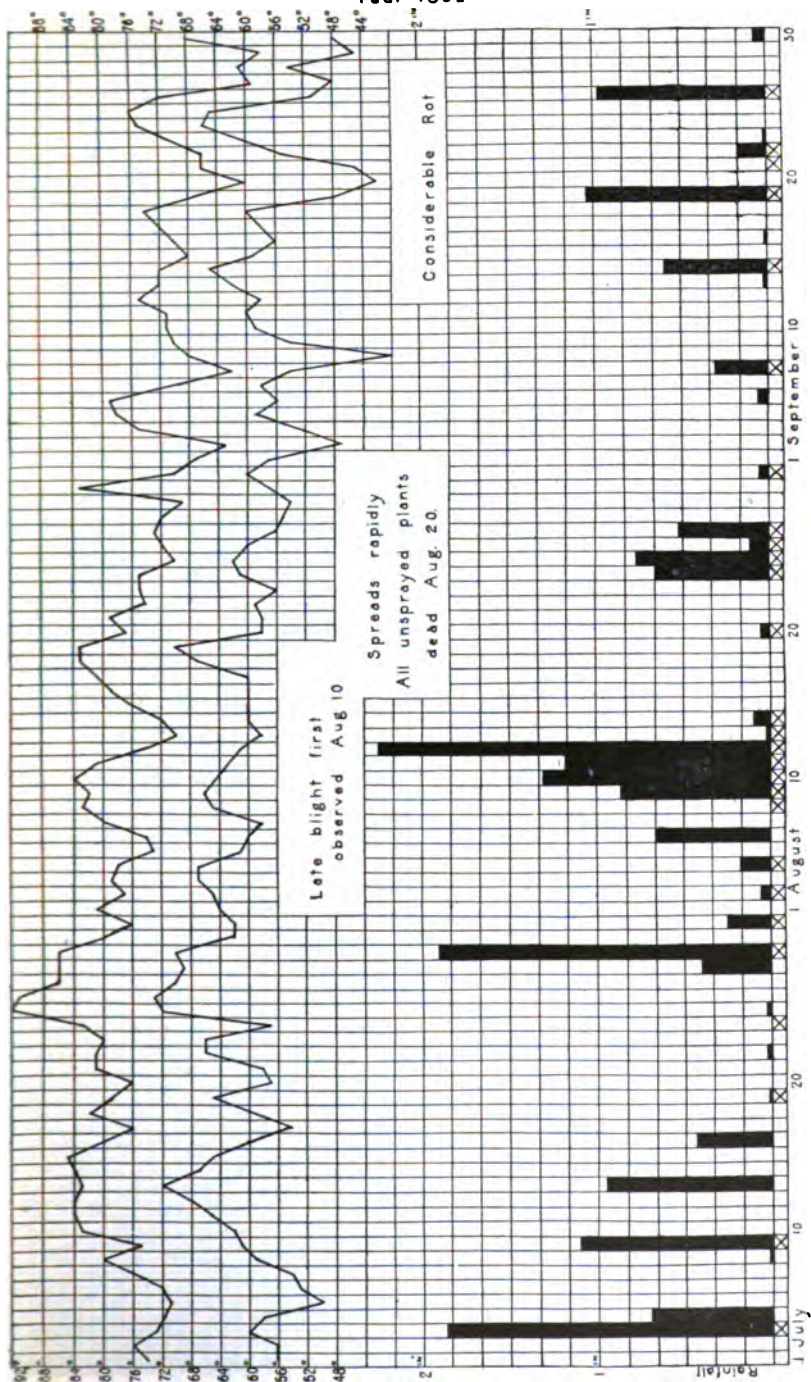
^a Vt. Sta. Rpt. 9, p. 67 (1895).

Year 1891



1892. "From August 6th to 12th almost ideal conditions prevail for the blight and reference to the records show that it in reality appeared August 10th, and progressed with unprecedented rapidity so that almost every potato plant was destroyed by it before August 20th."

Year 1892

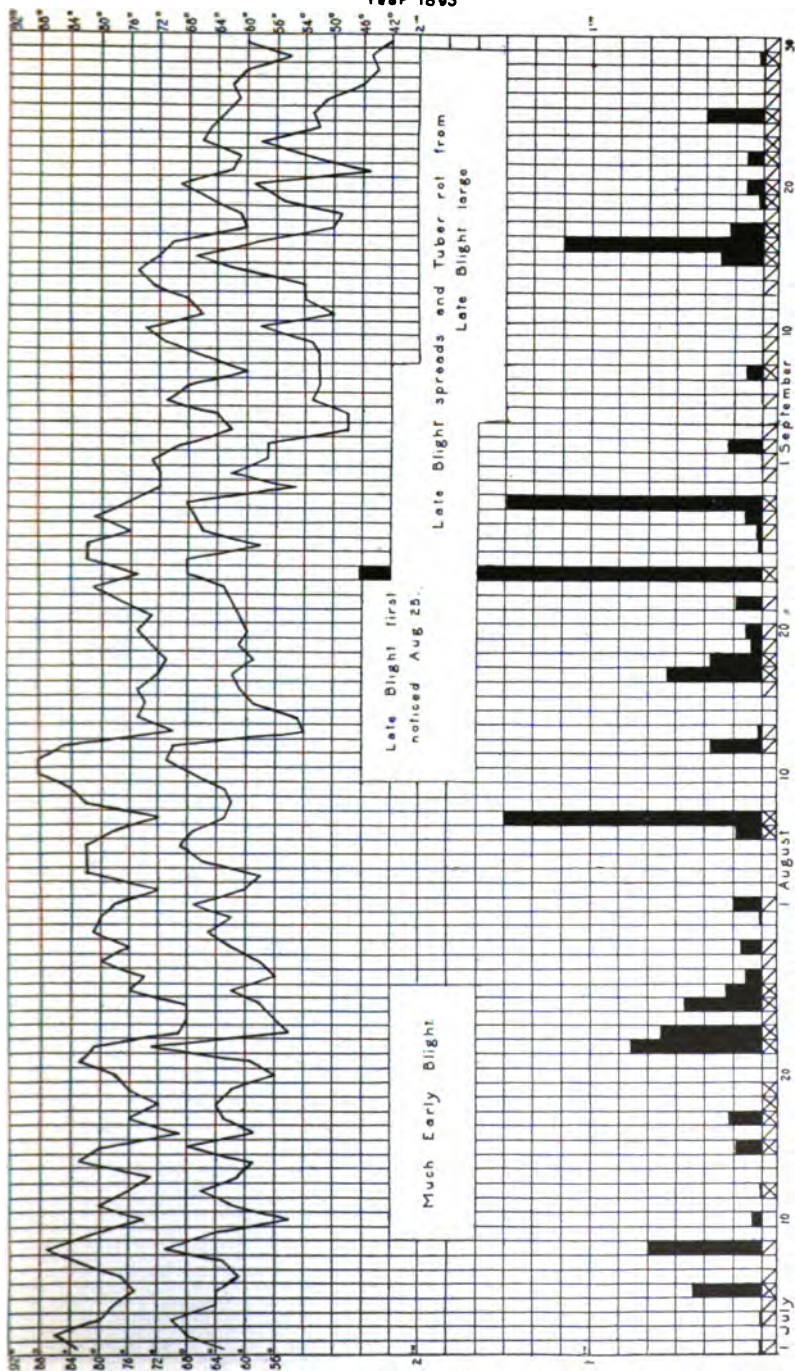


1893. "There were conditions favorable for the disease from August 7 to 13, but no blight was observed at that time. However, early potatoes whose tips were dead at the time the blight was first noticed, August 25, showed quite a percentage of rotten tubers; thus it is probable that the blight was present on these early potatoes at the period indicated by the charts as favorable, but escaped observation.

Another bit of evidence pointing this way is the fact that a piece of late potatoes adjacent to these early ones was attacked by the blight fully a week earlier than was another piece in an isolated locality, but planted with the same strain of seed.

The later conditions favoring the blight began about August 22, and the disease is recorded as under full headway by the 25th, and as continuing into September with unusually destructive results."

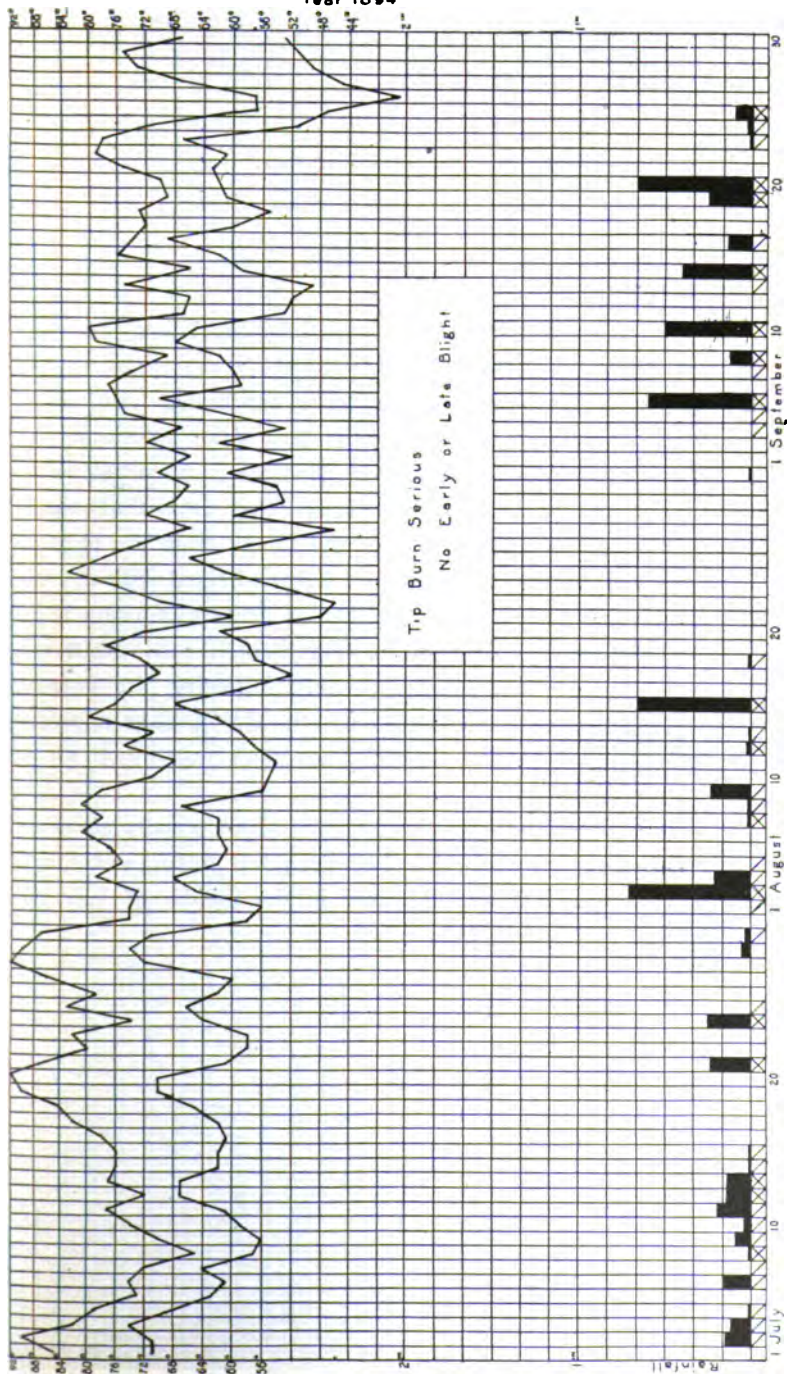
Year 1893



1894. "The weather conditions of this year were very peculiar and prevented the appearance of much blight. July was hot and dry while August was cool and dry. The average maximum temperature for July was 80.1° the minimum 64.4° ; the average maximum for August was 73.7° the minimum 58.3° . The rainfall for July was only 1.57 inches and for August 1.49 inches. The drought was the most severe in decades. No late or early blight was observed on the foliage, but a few tubers dry rotted in the bins showing that the disease had been present.

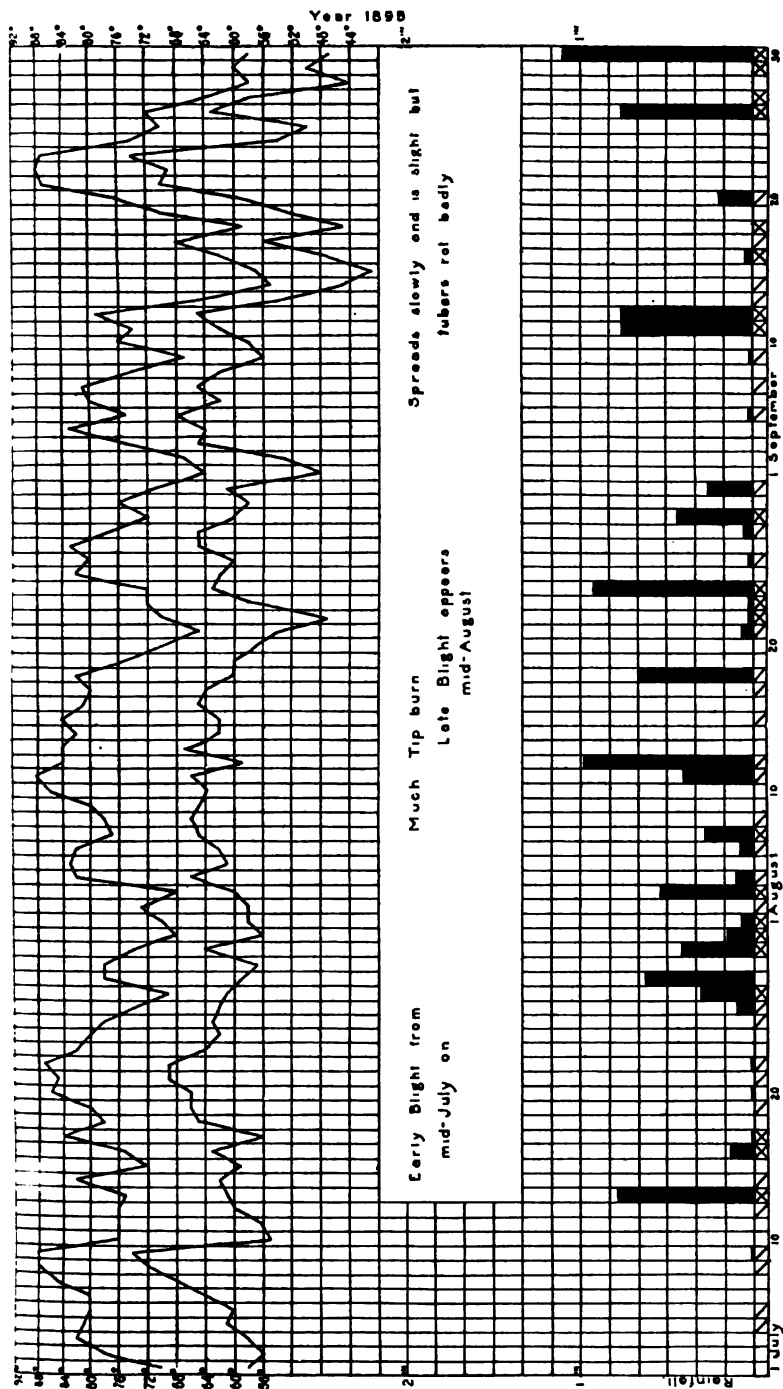
Tip-burn, of course, was prevalent and caused the early death of the potato foliage."

Year 1894



1895. "The late blight was tardy in developing this year although conditions were favorable for it during early August. The rise of temperature on August 4 continuing until about August 20 may have checked it if any stray infections occurred. The conditions in 1894 were decidedly unfavorable to the disease and very little could have carried over from that year in tubers, although an examination of the tubers from the plots on the Experiment station farm showed a few affected with dry rot. This would tend to lessen the number of centers of primary infection in the summer of 1895 making them few and scattered. In the latter part of August, probably following the drop in temperature, twentieth to twenty-fourth, the disease appeared and from then on spread slowly. The result was much rot to the tubers in the field."

"The tip-burn and early blight were about equally abundant on the experimental plots that had been left unsprayed during August. The early blight appeared in the middle of July and continued to the first of September."

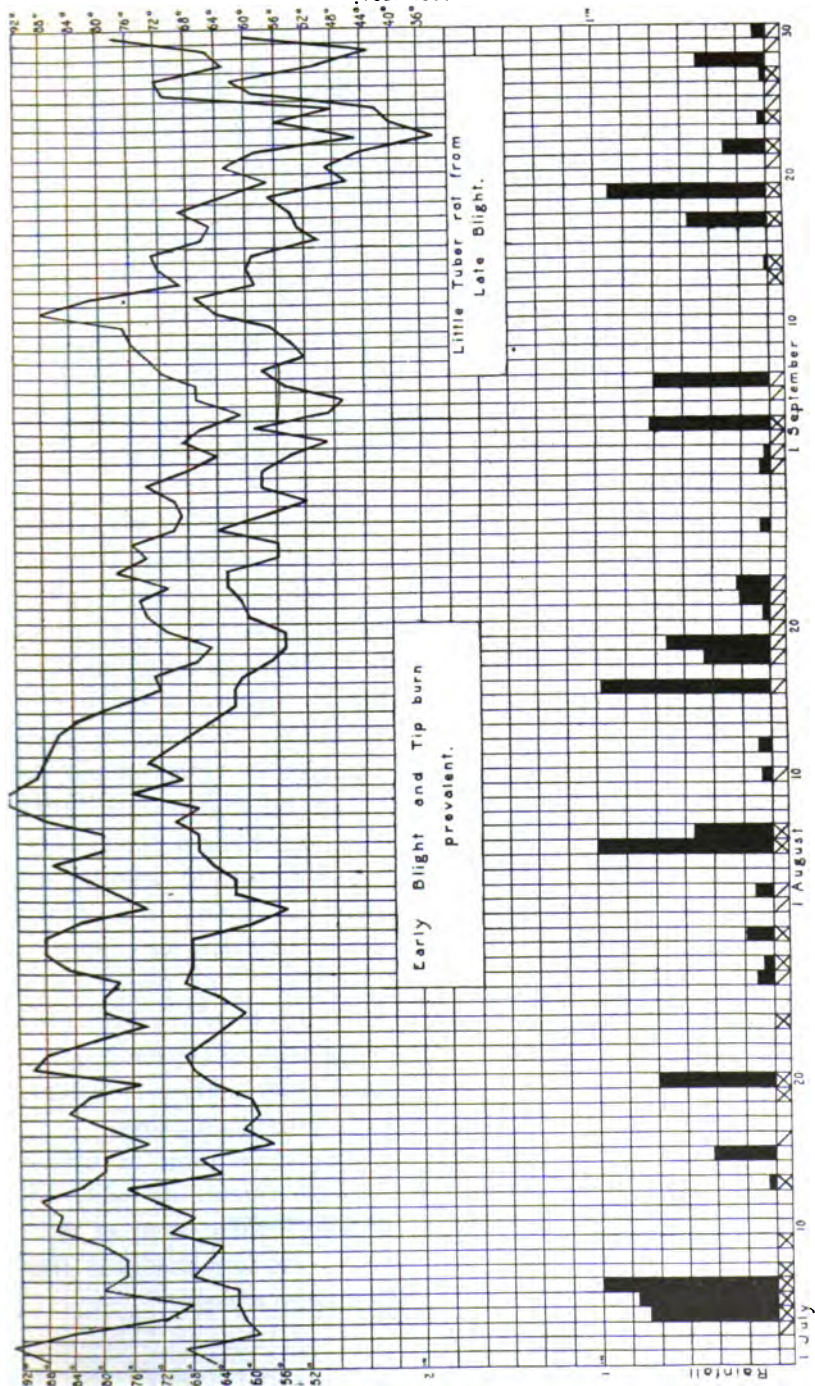


1896. Abundant infected tubers were undoubtedly carried over from the preceding season and the rainfall during July and August ought to have been sufficient to cause the disease to appear. The temperature continued high, however, and this may explain its absence at Burlington. Very little dry rot was found in the potato bins during the winter.

During the hot weather of July and early August the tip-burn and blight became prevalent and destructive.¹

¹ The statements made as to the prevalence of disease for the years 1896 to date are derived from those appearing in the several station reports for the corresponding years as cited in the footnotes on pages 225-246 of this bulletin, to which such persons as are interested are referred.

Year 1896.

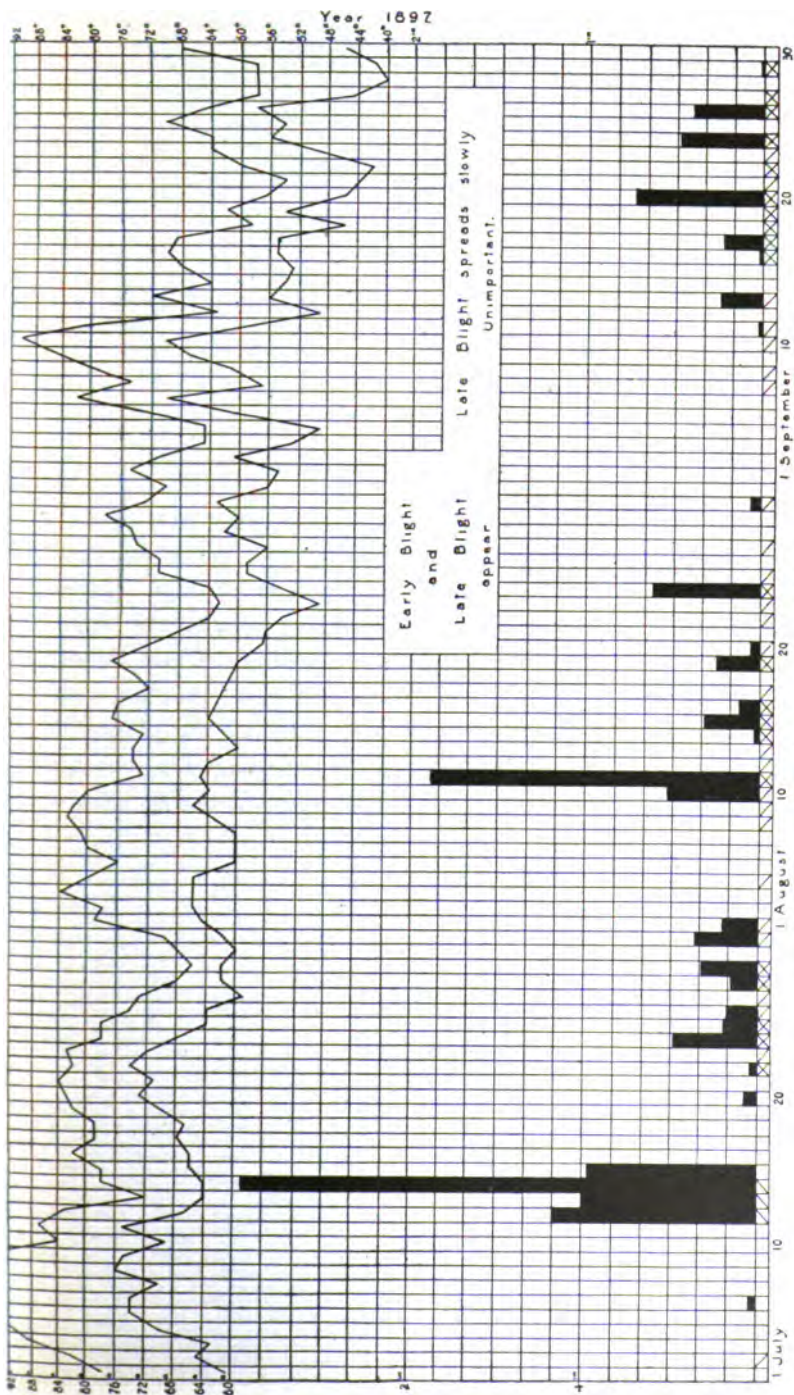


1897. A heavy amount of rainfall combined with much cloudy weather should have produced a bad attack of the *Phytophthora*; yet the disease did not appear until late August, when it developed with unusual virulence upon the earlier planted potatoes. The absence of many primary centers of infection from 1896 may, as in 1895, have been a prime factor in its late appearance. Tip-burn was prevalent and had already destroyed most of the foliage by the time the late blight appeared, the plants being so nearly dead before the *Phytophthora* began its spread that there was a proportionally smaller amount of rot than usual. The following interesting observations were made touching upon this situation.¹

"Owing to the prevalence of cloudy weather the potato plants at the beginning of August were constitutionally weak. Two conditions now operated in combination for their speedy destruction in most of the fields under observation. One was the exhaustive drain made upon the weakly tops consequent upon the formation of tubers; the second was the frequent alternation of exceptionally bright hot days with periods of cloudy or rainy weather. As a result tip-burn developed everywhere, and the greater number of potato plants about Burlington died during August from these causes before the fungus blight developed to any great degree. The relation of this tip-burn to rankness and succulence of growth was clearly shown on certain of our plants on rather poor sandy soil. A portion of these were given a heavy application of commercial fertilizer. The result was a ranker growth and finer looking plants on these fertilized plots up to the first of August. When the trial of resistance came, however, during the next three weeks these suffered considerably more from tip burn than did the unfertilized plants.

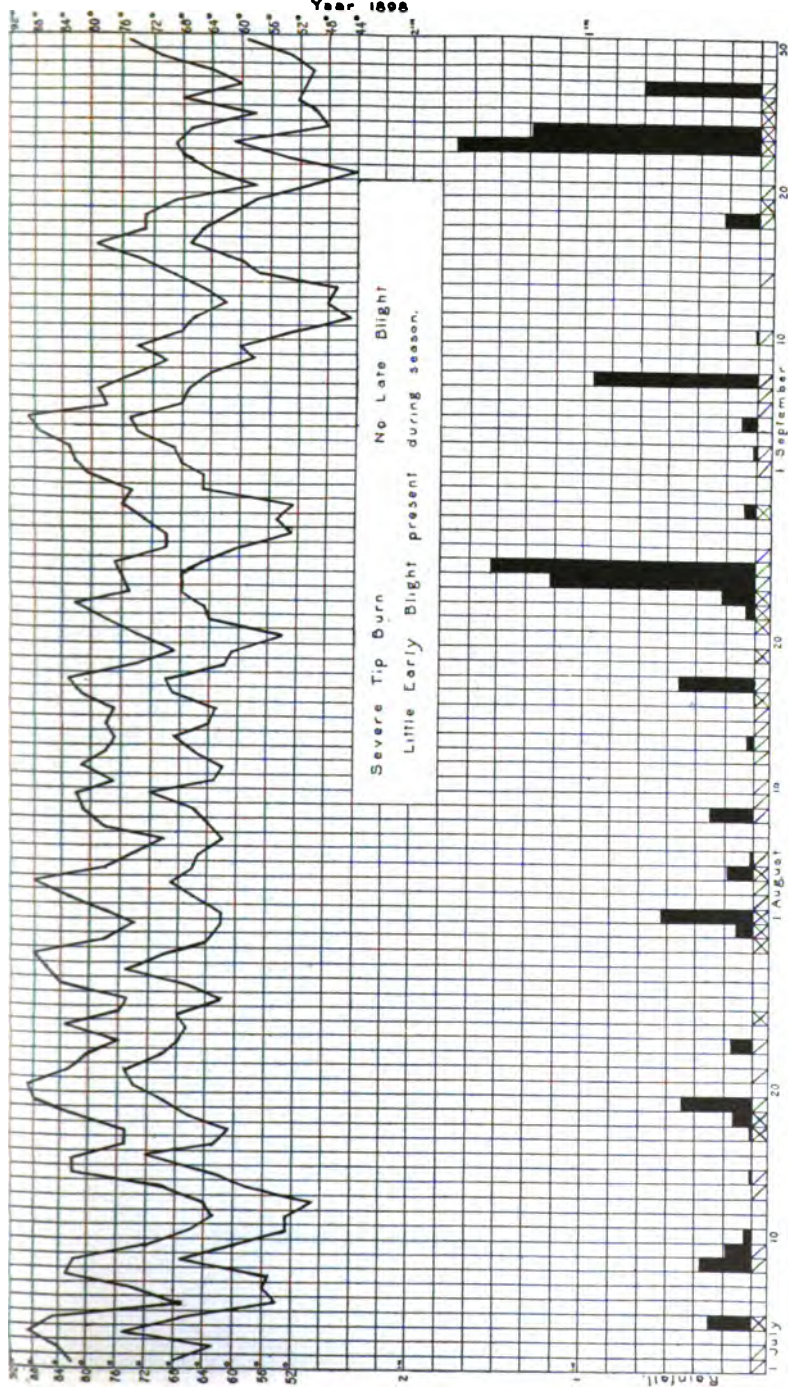
It is evident, therefore, that this same form of trouble which we term tip-burn may result from various and quite different unfavorable conditions, especially if these occur at about the time of rapid tuber formation. The conditions of 1897 were peculiar and are not likely soon to be repeated."

¹ Vt. Sta. Rpt. 11, p. 190 (1898).

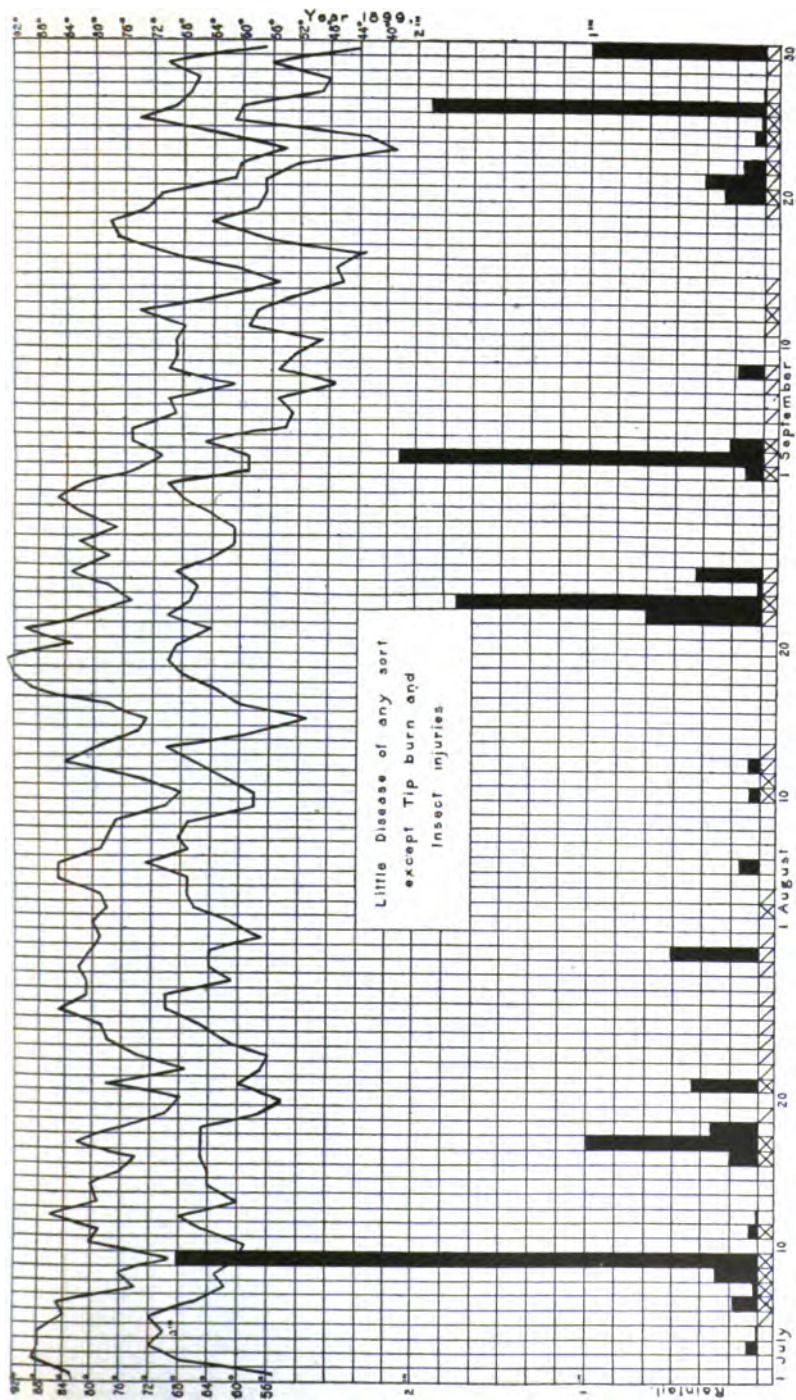


1898. The early and late blights were practically absent from the potato fields around Burlington. While the rains were numerous they were light, and drought resulted during mid-summer. The temperature remained consistently high from July 15 to September 5 with the exception of two minor drops of eight to ten degrees in the latter part of August. As a result much tip-burn occurred, practically all the plants on light soil dying during this period, manifesting the characteristic symptoms of tip-burn, while those more favorably situated suffered severely.

Year 1898

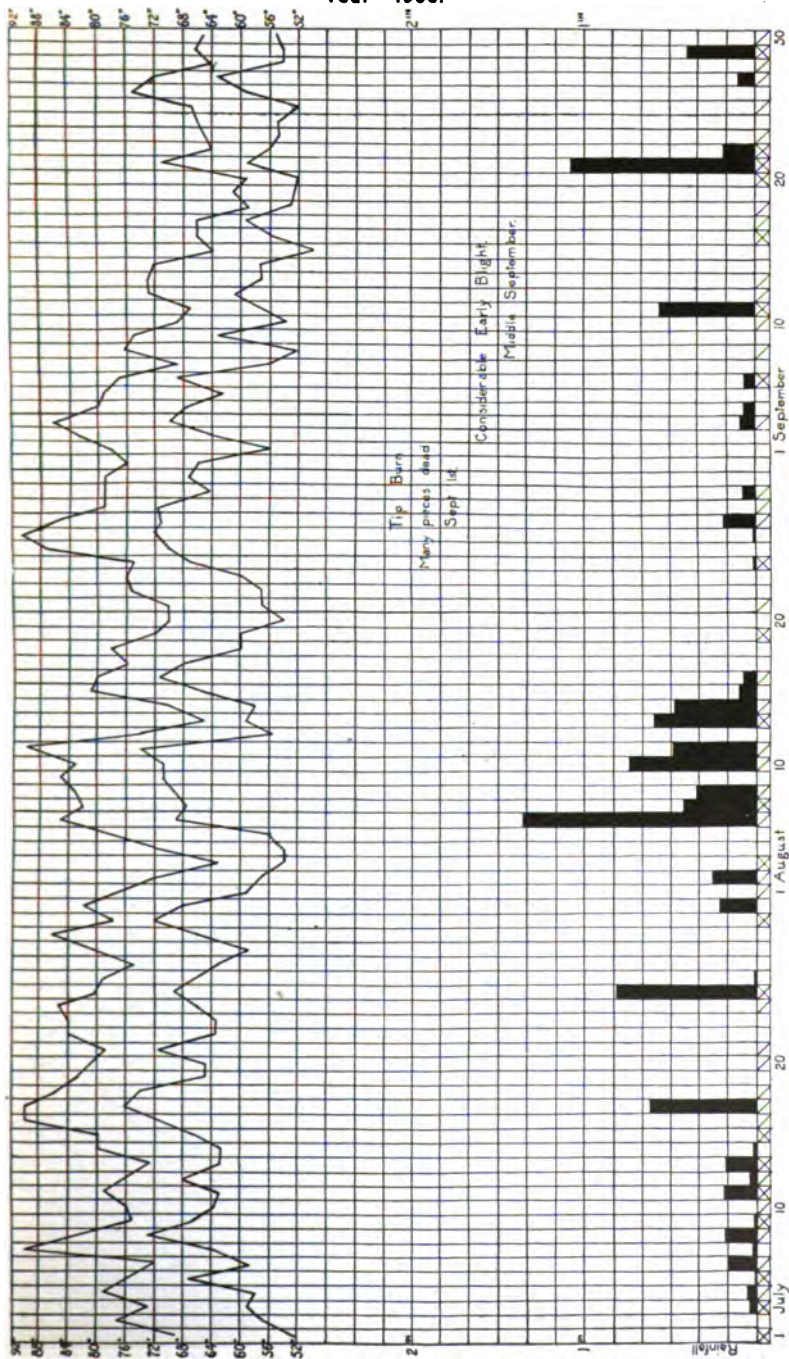


1899. Very little early or late blight was observed around Burlington as the season was very dry from mid-July until the latter part of August, after which time there seems to have been a fair amount of rain. The potatoes on light soils died during this period with all the characteristic symptoms of tip-burn. The yields were greatly reduced from tip-burn and insect injuries.



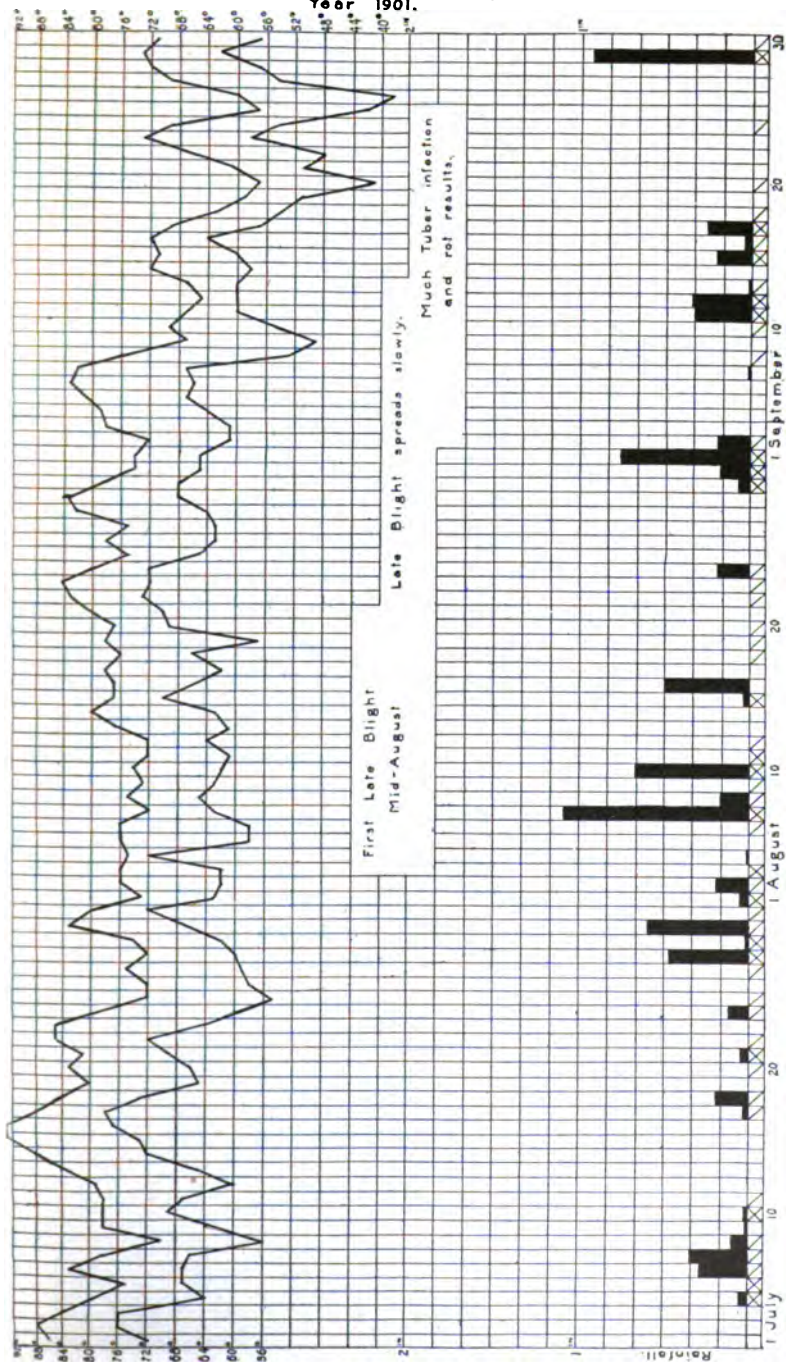
1900. The summer as a whole was a very dry one, the only protracted rainy weather occurring from August 6 to August 16. This was broken, however, by three fair days when there was no rainfall. As a result tip-burn was destructive and many pieces were dead at an earlier date than usual. The reduction of yields was due to this malady rather than to the presence of late or early blight. A little dry rot occurred in some of the fields.

Year 1900.



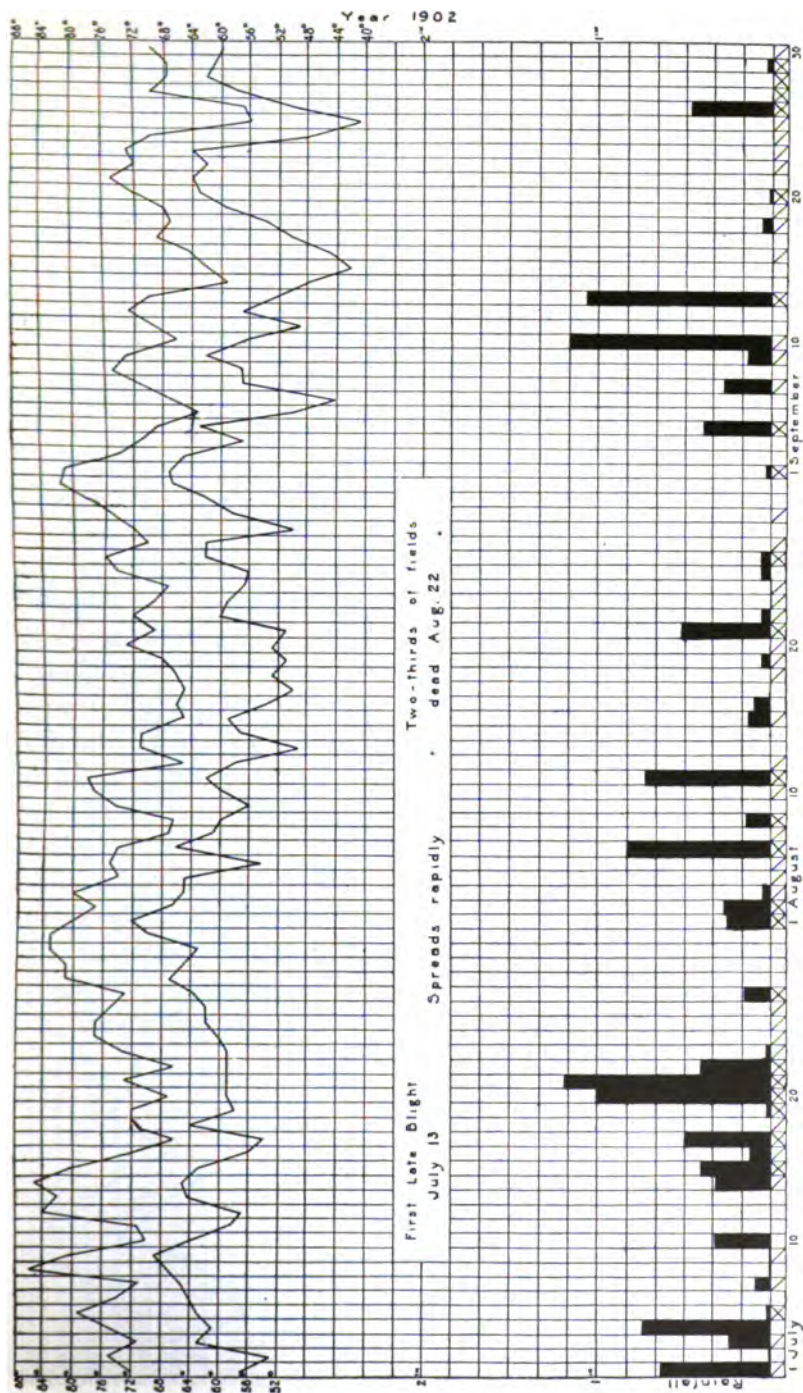
1901. The preceding summer had been a somewhat dry one and the summer months of 1901 were still drier; yet this year marked the reappearance of the late blight fungus. The weather following August 15 was not especially favorable to its spread, but there was enough rainfall and cloudy weather to keep it going during the latter part of August and the month of September. A serious rotting of the tubers occurred accompanied by a loss in some cases of from 65 to 90 percent of the tubers. The injuries from tip-burn and from early blight were less than usual, owing to the abundance of water due to frequent small rains and to a lack of high temperature.

Year 1901.



1902. The summer was moist and cool and the *Phytophthora* appeared at the earliest date on record here, July 13. The abundant infection from the preceding year undoubtedly hastened its appearance. Following this date there ensued a period of wet, cloudy weather, July 14-28, during which time the disease was spreading on the lower leaves of the earlier varieties of potatoes. On the later potatoes planted on higher ground its spread occurred largely during the first two weeks in August, August 1 to 11 being wet and cloudy. During this same period the vines of the early varieties succumbed. A similar period later in the month, August 18-27, finished up the later varieties, so that a canvass of the vicinity of Burlington on August 23rd showed the plants in two-thirds of the fields entirely dead and rapidly dying in the remainder. A large amount of rot of the tubers showed on the moister soils.

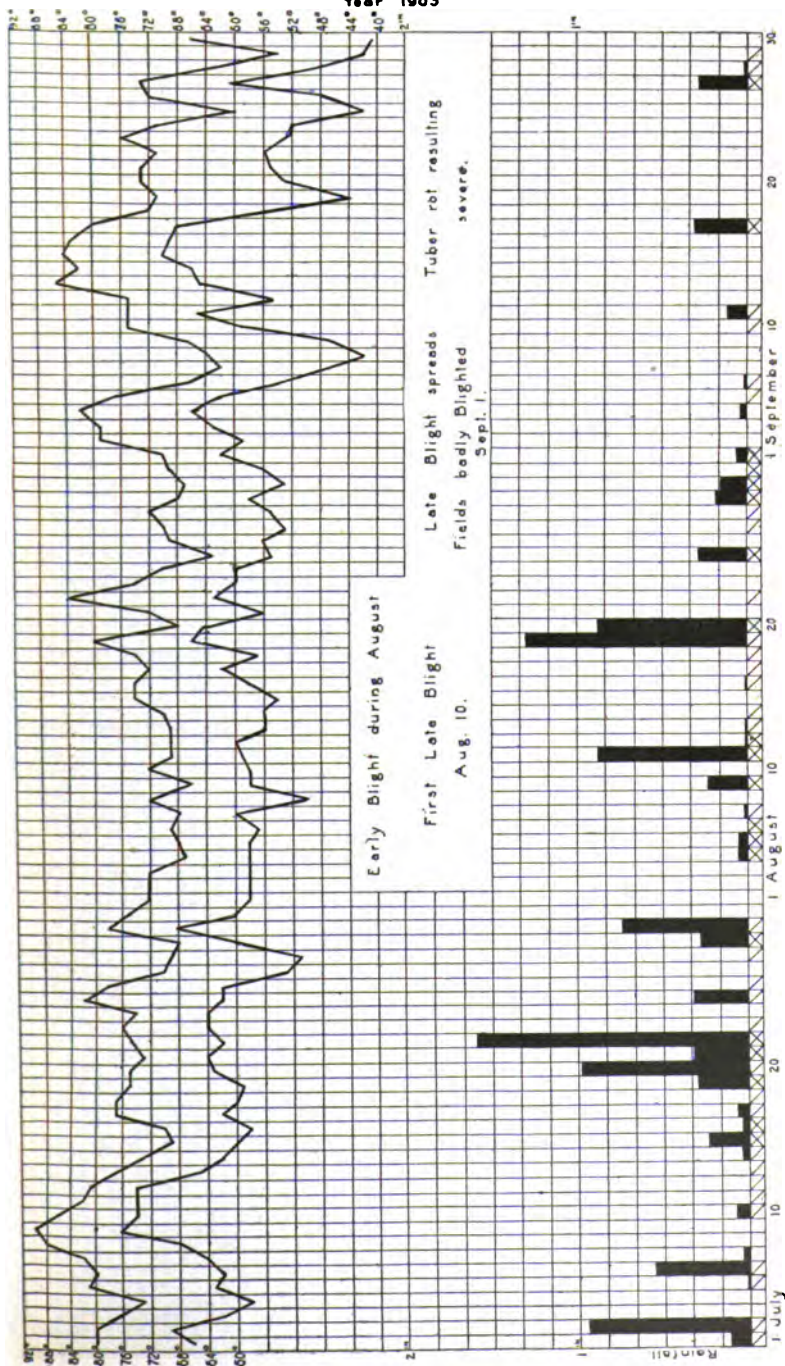
The early blight was less prevalent than usual and, the rainfall being abundant, tip-burn did not manifest itself.



1903. The abundant infection which must have carried over from 1902 did not produce immediate results in the potato fields during this summer, owing to the unusual weather conditions. From the middle of April to the first week in June, there was practically no rainfall. The potato plants did not grow until the rains came at this latter date. By the middle of August, owing to the rains of June and July, there was a fine stand of tops. With the infection of *Phytophthora* from the preceding year it would seem that a period of damp cloudy weather, such as that occurring from July 10-25, would have caused it to appear; but it was not observed until August 10. It will be noted that while this date was not coincident with a period of heavy rainfall, yet it was coincident with one of low temperature. The relatively cool weather continued throughout August and the disease spread gradually. Practically every field around Burlington, except some pieces on sandy soil, was badly blighted before September first. September was characterized by practically no rainfall and by but few cloudy days, yet the rot from the August infection was general and severe.

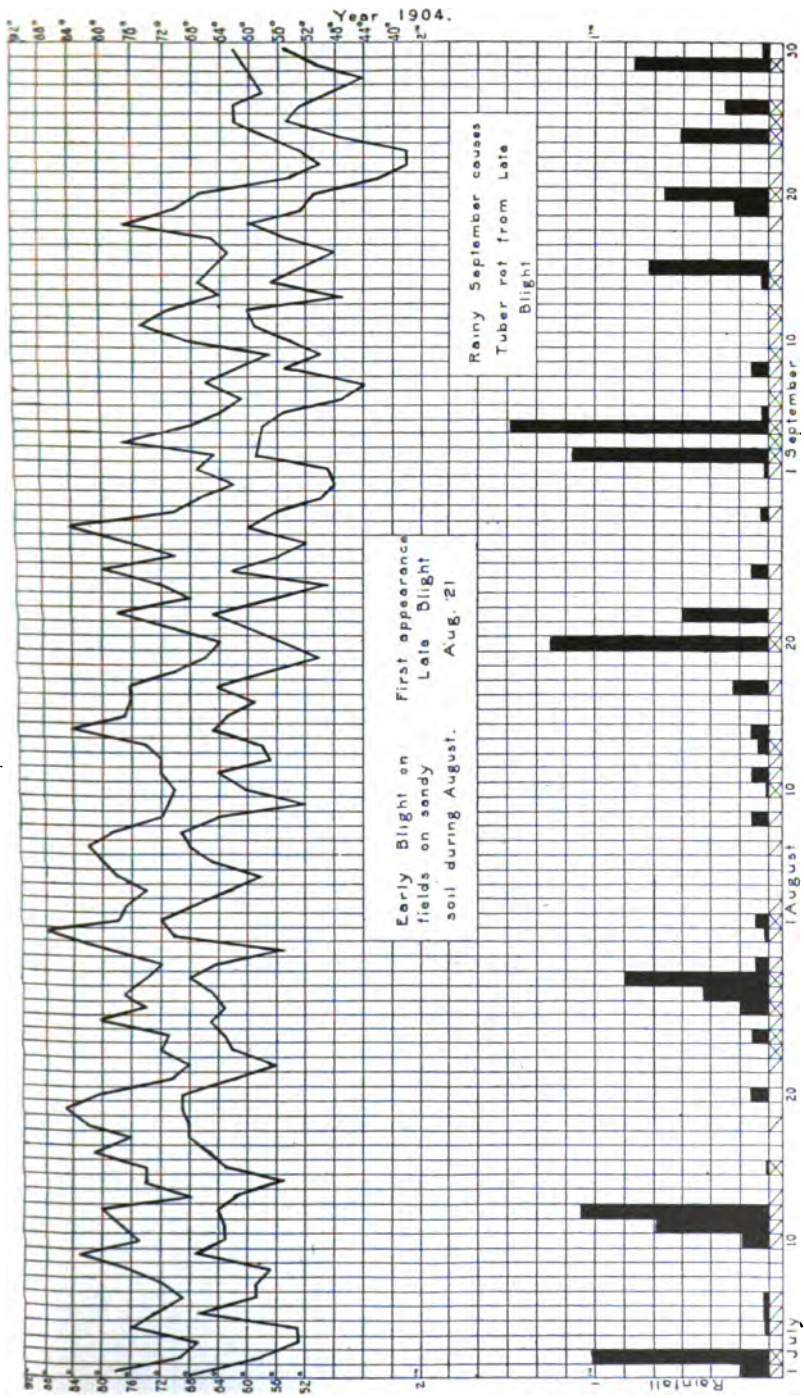
The early blight and tip-burn were not serious, although the former appeared during August on the light sandy soils.

Year 1903



1904. The first late blight was observed on August 21. July and August had been fairly normal as to temperature and rainfall and the infection in 1903 was late in developing. September was rainy with much cloudy weather. The blight spread slowly, not damaging the foliage as much as usual but resulting in much dry rot.

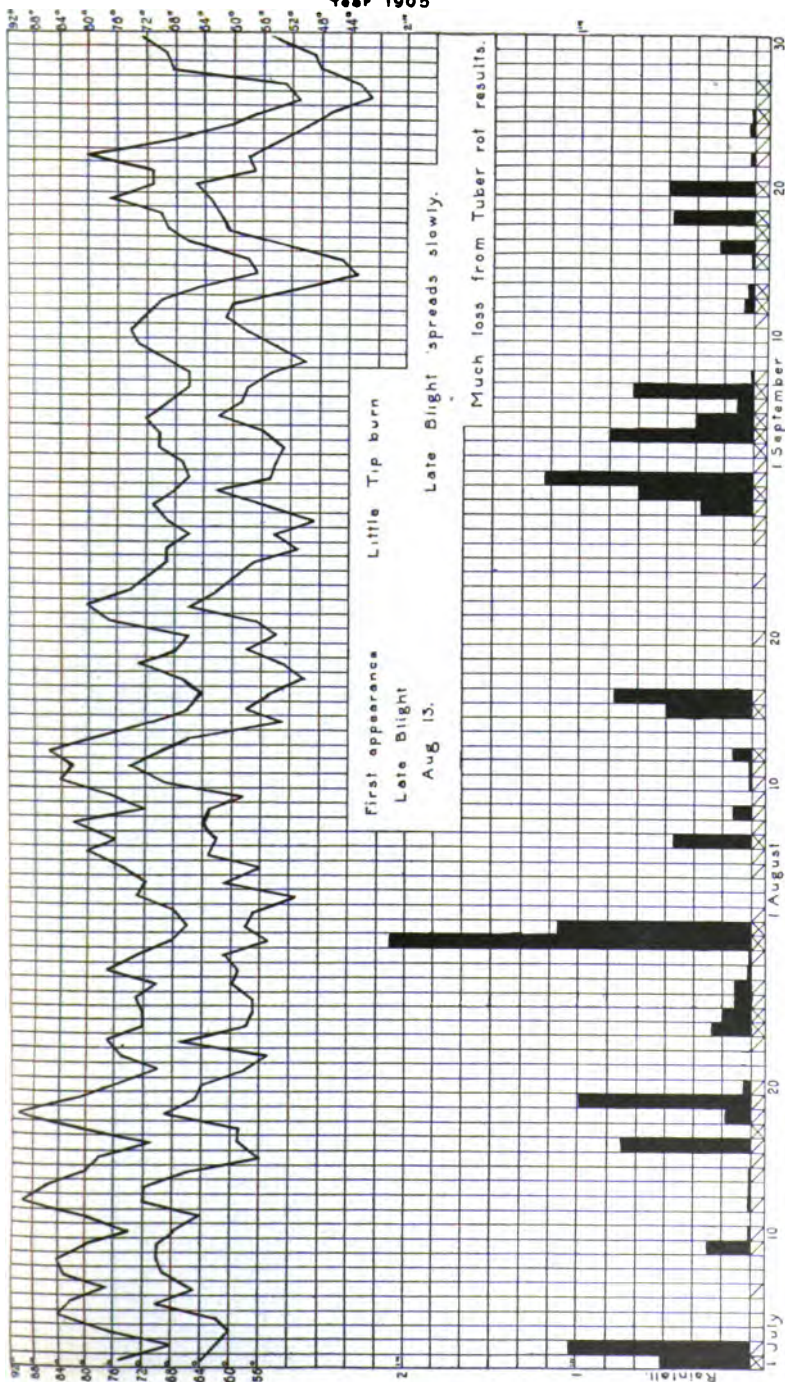
The early blight was destructive in some fields on sandy soil near Burlington.



1905. Abundant rains during July produced a luxuriant foliage development, and the first late blight was observed on August 13. Heavy rains had occurred on July 30 and 31 and smaller ones on August 6 to 12. Dry weather followed the advent of the disease from August 17 to August 28. This did not particularly favor its spread, but during the first week in September, low temperatures, cloudy weather and almost daily rains caused it to become generally conspicuous. From September 11 to 25 the weather was rainy and cloudy and the conditions were ideal for rot. Many fields on low or heavy soil were not worth digging.

Tip-burn and early blight were comparatively unimportant.

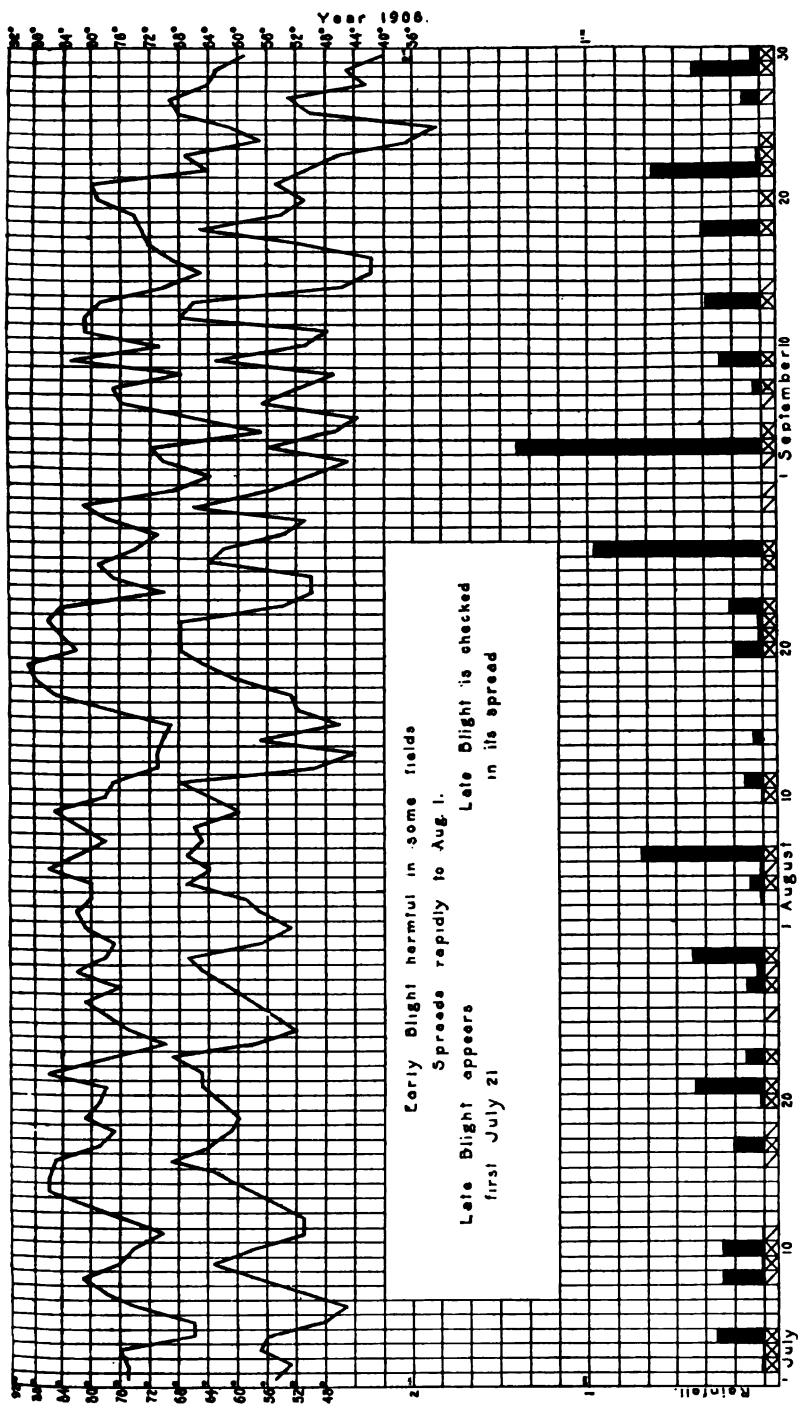
Year 1905



1906. Late blight first appeared at Burlington probably between July 20 and August 1. It will be noticed that while there were no heavy rains during July to favor its spread, "the moist warm weather of early July favored the fungus."¹ The infection of the tubers had been so thorough the preceding year that the recurrence of the malady was certain if weather conditions were even moderately favorable. During the latter part of August, and the month of September, however, the weather conditions seemed to check its spread. The reason for this is not entirely clear, but the high temperature and lack of rainfall from August 6 to August 27 may have served to retard it, to dry it up as it were, and the rainfall and low temperatures of September may have served to revive it. Some tuber rot occurred, but there was practically none seen in the main crop.

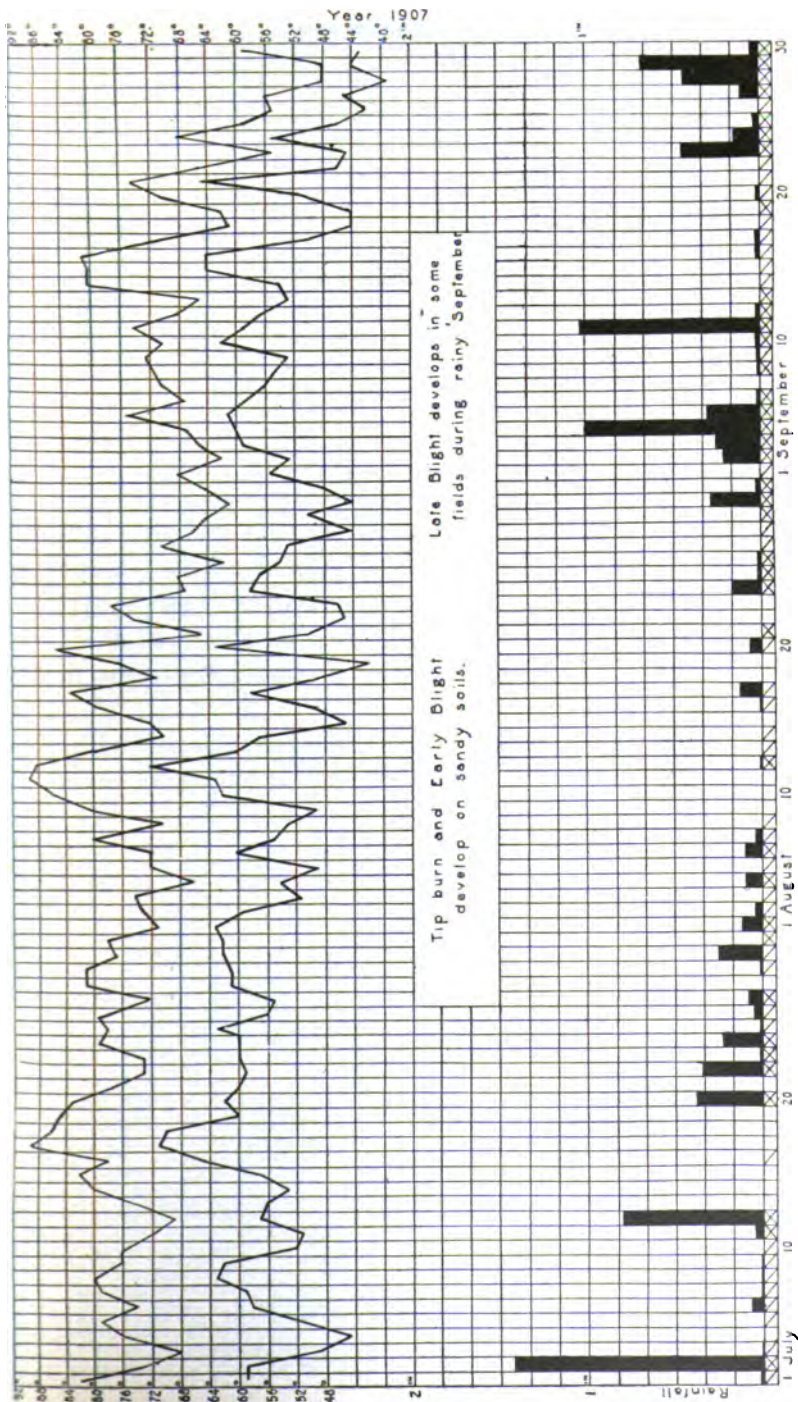
The early blight was destructive on light sandy soils during late July, and by August 1 it was hard to find a leaf unspotted by this blight in some fields near Burlington. Tip-burn was common after the hot, dry weather of late August.

¹Vt. Sta. Rpt. 19, p. 228 (1906).



1907. This summer was an average one during July and August as to temperature and rainfall. September, however, had few clear days and rainfall was abundant. As a result the late blight appeared in certain fields around Burlington.

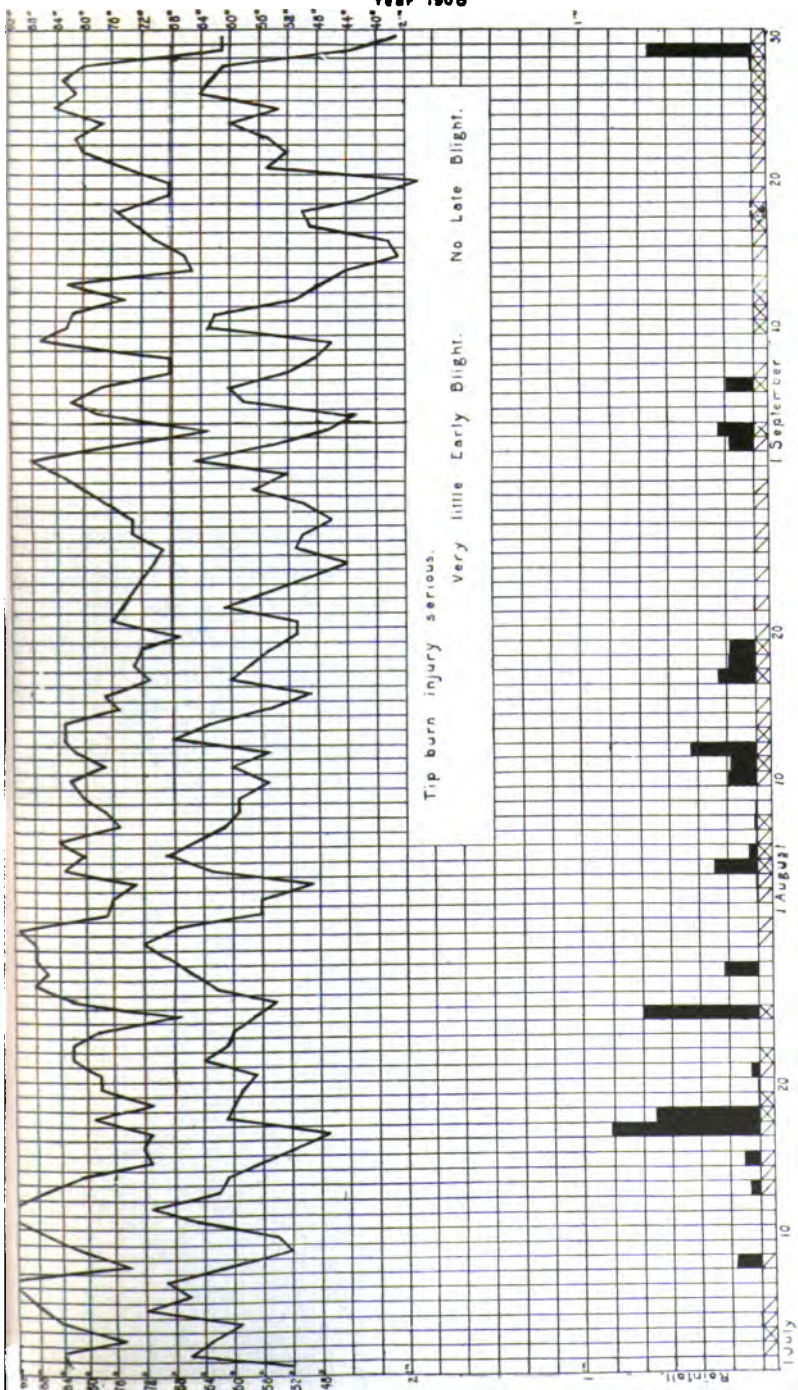
The lack of rainfall during late July and early August caused the development of much tip-burn as well as of early blight on the lighter sandy soils.



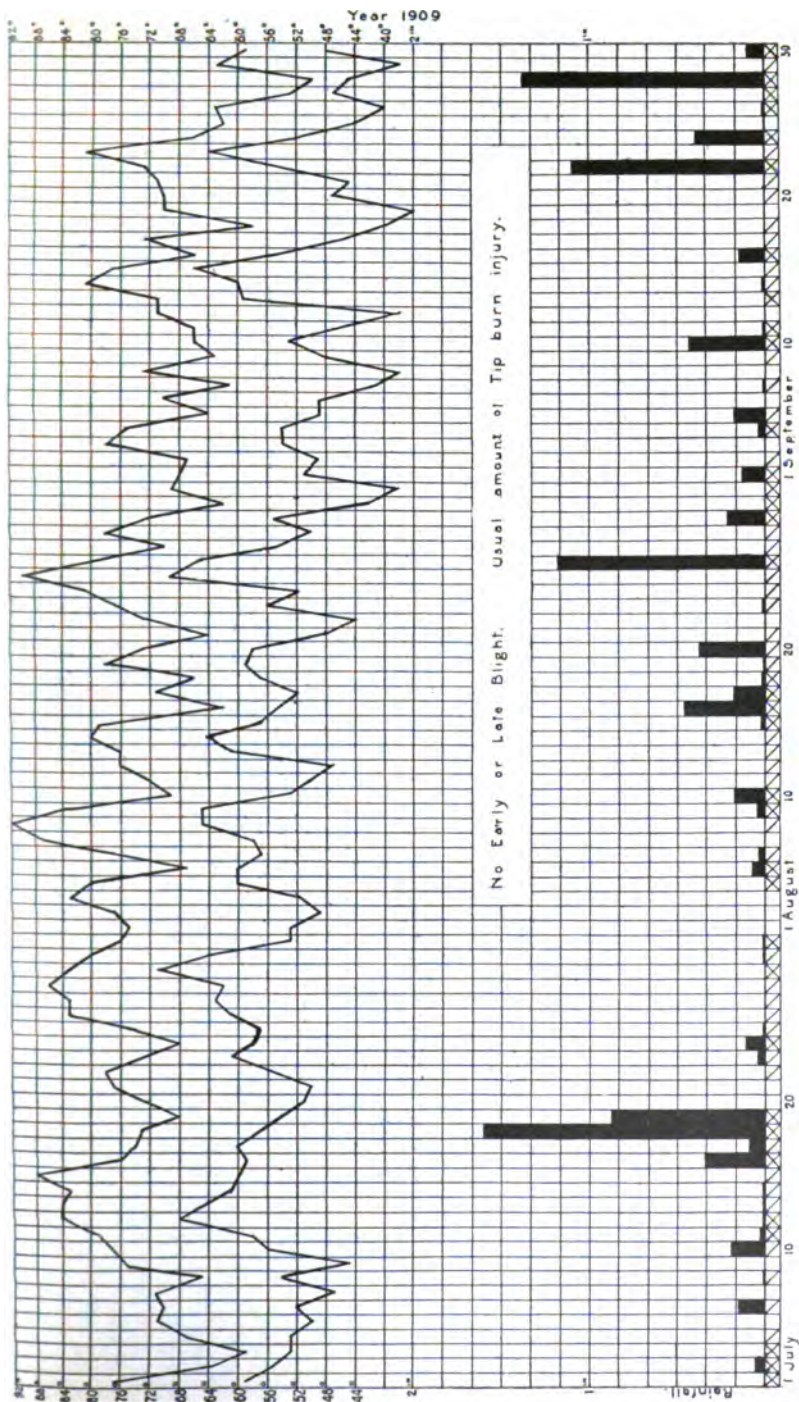
1908. The late blight was not found this year in the potato fields around Burlington. The very light rainfall was undoubtedly responsible for this. The rainfall of the preceding two years had also been below normal and any tuber infection carried over into 1908 from them must have been small. The dry weather of this year would have prevented the spread from any such diseased tubers.

On the other hand, owing to the light rainfall and high temperatures, some early blight appeared and tip-burn injuries were serious.

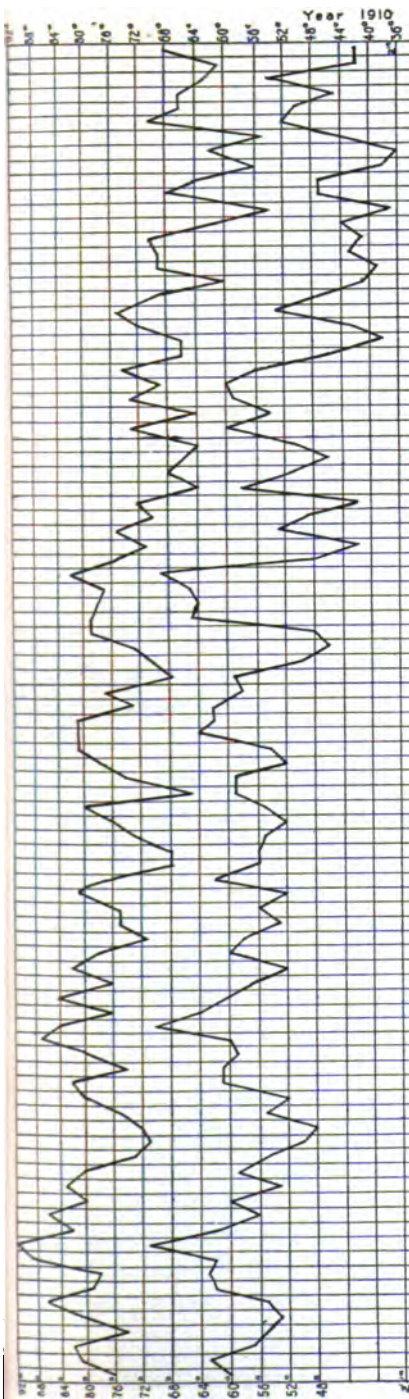
Year 1906



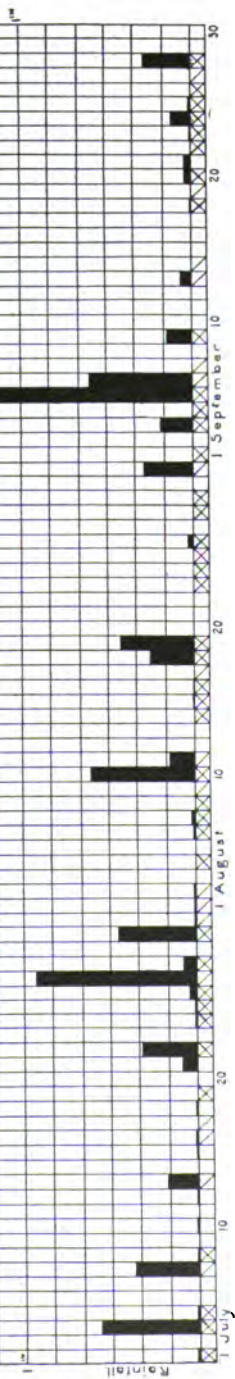
1909. Late blight did not appear this year in the vicinity of Burlington. The preceding year had been such a dry one that no tuber infection was bequeathed by it to 1909. The rainfall, while abundant and about normal, was well distributed and no opportunity for spread of late blight presented itself. There was enough moisture, however, to prevent any early blight and no more than the usual amount of tip-burn injury appeared after the middle of August.



1910. The conditions this year were similar to those of the preceding one and no late or early blight appeared, and only the usual amount of tip-burn injury resulted. The two preceding years had shown no late blight and the rainfall distribution was not such as to spread any chance infection however introduced.



No Early or Late Blight: Usual amount of Tip burn injury.



AVERAGE MAXIMUM AND MINIMUM TEMPERATURE

Year.	July		August		September		Rainfall in inches			
	Max.	Min.	Max.	Min.	Max.	Min.	July	Aug.	Sept.	Total
1891	90.0	51.0	90.3	51.0	85.0	43.0	3.48	3.25	2.44	9.17
1892	92.2	50.5	84.7	54.0	79.0	40.0	7.64	8.36	3.22	19.22
1893	77.5	62.6	77.6	62.8	65.7	51.2	3.74	8.31	2.45	14.50
1894	80.1	64.4	73.7	58.3	71.4	57.1	1.57	1.49	2.88	5.97
1895	79.0	62.1	77.7	61.3	70.8	56.9	2.46	4.84	3.64	10.94
1896	81.7	65.2	77.8	62.5	67.8	53.3	3.83	4.09	3.59	11.51
1897	81.4	67.5	74.7	60.7	68.1	53.6	8.48	4.08	2.13	14.69
1898	78.6	64.4	77.2	63.7	71.2	57.8	1.51	4.58	5.01	11.10
1899	78.8	63.2	80.3	64.9	67.7	53.4	5.30	3.82	6.38	15.50
1900	79.9	65.3	77.6	63.7	70.2	57.3	2.73	5.25	3.20	11.18
1901	80.9	66.8	76.8	64.8	69.8	56.5	2.29	3.18	3.07	8.54
1902	76.7	62.8	73.1	59.7	69.7	56.4	6.23	3.17	3.68	13.08
1903	77.1	63.8	70.8	57.7	72.6	55.6	6.68	4.02	.80	11.50
1904	75.5	62.6	73.9	59.5	64.0	51.7	4.19	2.56	5.84	12.59
1905	77.1	62.9	72.9	59.1	67.3	54.2	7.67	3.98	4.32	15.97
1906	77.4	58.4	78.9	59.0	70.0	50.0	2.33	2.26	3.59	8.18
1907	77.7	58.6	73.4	53.8	66.2	52.8	3.68	1.05	4.76	9.49
1908	82.1	61.2	76.3	55.8	74.8	51.2	2.66	1.65	1.15	5.46
1909	75.5	57.2	75.5	55.0	67.6	48.6	4.06	2.83	4.36	11.25
1910	79.8	58.5	74.7	55.6	66.0	46.9	3.06	2.76	2.75	8.57
Average	79.9	61.4	76.8	59.1	70.2	52.3	4.17	3.77	3.46	11.40

GENERAL CONSIDERATIONS

In the vicinity of Burlington there have been during the past twenty years two severe, general late blight periods and two periods when little or no blight was present. The first blight period was from 1890 to 1894; the second from 1901 to 1906. The two periods when either the disease did not occur or was not abundant were from 1894 to 1900 and from 1906 down to and including the past year 1910. The date of publication of this bulletin is too early to admit of prediction or of statement as to the probabilities of 1911.

Rainfall has much to do with the spread of this disease. The following table shows the total rainfall precipitation for each year during the summer months and the prevalence of late blight:

Rainfall during July, August and September	Prevalence of late blight
1891..... 9.17 inches	Some blight.
1892.....19.22 inches	Much blight and rot.
1893.....14.50 inches	Much blight and rot.
1894..... 5.97 inches	No blight.
1895.....10.94 inches	Much tuber rot.
1896.....11.51 inches	Very little blight or rot.
1897.....14.69 inches	Some blight and rot.
1898.....11.10 inches	Little blight or rot.
1899.....15.50 inches	Little blight or rot.
1900.....11.18 inches	A little dry rot.
1901..... 8.54 inches	Much blight, 65-90% tubers rotten.
1902.....13.08 inches	Severe blight and rot.
1903.....11.50 inches	Severe blight and rot.
1904.....12.59 inches	Some blight, much dry rot.
1905.....15.97 inches	Severe blight and rot.
1906..... 8.18 inches	Some blight, little rot.
1907..... 9.49 inches	A little blight.
1908..... 5.46 inches	No blight.
1909.....11.25 inches	No blight.
1910..... 8.57 inches	No blight.
Average...11.4 inches	

In general it is true that a very rainy season is likely to be accompanied by an epidemic of the disease. This fact is well illustrated by the seasons of 1892, 1893, 1902 and 1905. But there are years like 1897 and 1899 when the rainfall was nearly as heavy and when there was little or no late blight, while on the other hand in seasons like those of 1895, 1901 and 1904 it was hardly above the average, yet the disease was abundant; in fact 1901 was one of the worst seasons on record both as regards damage to foliage and to tubers; yet the rainfall was small. The year 1894 is a well marked example of how the lack of rainfall prevents the spread of late blight and stops the disease, in spite of its great prevalence during the preceding years.

Clearly it is not easy to define the exact weather conditions that call forth an epidemic of *Phytophthora infestans*. Doubtless rainfall is the chief factor, but it is one that is limited in its effects by temperature and sunshine and also, probably, by winds. Given a high temperature and a clear sky the moisture from a heavy rainfall is soon vaporized, whereas when the thermometer ranges low the water from the same rainfall would remain cling-

ing to the plants. Under these latter conditions the parasitic fungus would have a chance to germinate its spores and to penetrate the potato leaf. A vitally essential piece of data, therefore, in the adequate study of these relations is a statement as to the humidity of the atmosphere at the level of the potato plant. Unfortunately this is not at hand. Had it been it would seem that we might explain, if not the appearance of *Phytophthora*, at least the cause for its spread. However, the rainfall, temperature and character of the day, i. e., whether cloudy or fair, afford an approximate idea of the amount of moisture in the atmosphere and enable one to deduce the probabilities as to humidity with a fair assurance of essential accuracy.

During the 20 years there have been two cases of this malady being stopped after a series of years when its ravages were serious; in 1894, when a very dry season checked it; and in 1906, after five bad blight years, by the very light precipitation of that season, becoming entirely eliminated in 1908.

There has also been only one example of the reappearance of the blight after a period of scarcity. This was in 1901. This season's record is anomalous. The cause of the severity of the rot is hard to explain. The foliage blight does not seem to have been excessive, yet evidently there was enough everywhere present in the field thoroughly to infect nearly every tuber. The rainfall, however, was below the normal and the temperature was not far from the average. There had been but little *Phytophthora* observed during the five years preceding 1901, although the weather conditions of some of these seasons, such as 1899, had been apparently favorable to its development. Fifty-seven percent of the days during the three summer months of 1901 were cloudy or partly cloudy as compared to 60 percent in 1900 and 54 percent in 1899. In other words, the summer of 1901 seems to have been a fairly normal season so far as rainfall, temperature and cloudiness were concerned; yet the disease reappeared after a partial absence of about five years, the fungus was everywhere present and from 65 to 90 percent of

the tubers rotted. It is not clear as to the reason for the steady spread of the fungus, but it may have been due to a relative lack of wind wherewith to dry up such moisture as fell. On this point unfortunately we have no data, since the weather station was not established until 1908.

In connection with the reappearance of the disease there is always to be borne in mind the manner in which the fungus causing it is perpetuated from year to year. Tubers infected with dry rot are commonly supposed to be the source of primary infection. It is a moot question whether these were sufficiently numerous to incite the spread of the malady attained in 1901, following a long period when affected tubers must largely have been destroyed. It is this uncertainty that has brought into prominence the hypothesis that there exists some type of resting spore, capable of withstanding such unfavorable conditions. Moreover the possibility must not be forgotten of the spread of the disease as a wave of infection over large areas from comparatively small centers, such as low lands along rivers where it is able to perpetuate itself.

While conditions leading to the occurrence and spread of the blight seem to be meteorological in their nature, the condition of the plant itself must also have much to do with the outcome. The malady appears to have been frequently destructive in seasons such as 1892, 1893, 1902, 1903 and 1905, characterized by rainy Julys and Augusts. Such weather conditions incite the growth of luxuriant foliage which readily falls a prey to the fungus, being over-large and of low resistant powers.

The tip-burn and early blight are diseases of the drier seasons. Particular note of this fact was made with reference¹ to tip-burn in the report for 1897, when the crop growth was very poor and the tip-burn highly destructive. The relation of these diseases to rainfall and temperature is an important and interesting one, especially in connection with the study of the occurrence of the late blight. It would seem that the potato plant

¹Vt. Sta. Rpt. 11, p. 190 (1898).

leads a precarious existence: too little moisture leads to early blight and tip-burn; too much moisture is likely to result in its invasion by late blight. If the foliage is too thin and lacking in water it is likely to suffer from tip-burn and early blight, while if rank and succulent, the late blight may attack it.

In conclusion it may be well to urge the importance of data similar to that collected here for the past twenty years on potato diseases. Even twenty years is a too short period for such a study; a hundred would be much better. It is largely by such studies that the habits of the parasitic fungi in the field can be brought to light. Laboratory studies, while valuable and absolutely necessary, still lack many of the essential factors which are only operative under natural conditions.

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UNIVERSITY OF VERMONT
AND STATE AGRICULTURAL COLLEGE

VERMONT AGRICULTURAL
EXPERIMENT STATION

BURLINGTON, VT.

BULLETIN No. 160

JUNE, 1911

**Commercial Fertilizers
Limes and Liming**

BURLINGTON:
FREE PRESS PRINTING CO.,
1911.

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Address all communications not to individual officers but to the Experiment Station, Burlington, Vt.

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Experiment farm and buildings are on the Williston road, adjoining the University grounds on the east.

*In cooperation with Bu. An. Ind., U. S. Dept. Agr.

BULLETIN 160: COMMERCIAL FERTILIZERS

LIMES AND LIMING

By J. L. HILLS, C. H. JONES, P. A. BENEDICT and W. B. DERRY

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SUMMARY

III. Results of inspection. The Station has drawn from dealer's stocks and analyzed 157 licensed brands, the output of 14 companies, all this year's goods. Four licensed brands were not found on sale.

1. Quantity of plant food. Ninety-three percent of the brands met their guaranties. Two brands by a minute margin failed to afford a commercial equivalent of the promises made for them. This outcome equals last year's favorable showing and is the best in years.

2. Quality of plant food. The quality of the crude stock used in furnishing phosphoric acid and potash seemed to be beyond reproach. To be sure an inferential claim that sulphate of potash was used, is made for two-thirds of the brands, while as a matter of fact only five brands contain any appreciable quantities of sulphate; but this quibble on the

part of manufacturers is now well understood. More mineral nitrogen was used than hitherto; even the low grade brands carried it. Ten companies continue to purvey an organic nitrogen which is above suspicion. It is to be deplored that this cannot be said of all companies, for organic nitrogen of low availability was used in a few brands. Attention is especially directed to the matter on pages 319-327 touching this situation. Pages 311-329.

IV. Selling prices and valuations. The average selling price was \$31.41; the average valuation, \$19.53. One dollar in three spent for mixed fertilizers was paid to the manufacturer, railroad, and selling agent for their work, while but two of the three were paid for plant food. But 56 cents' worth of plant food was bought for a dollar in average low grade goods, and 62 cents' worth in medium grade goods. The average high grade brand, however, afforded 65 cents' worth for a dollar. Some Vermont consumers paid fully twice as much for plant food as did others. Pages 329-338.

VI. The analyses of the fertilizers sold in Vermont this year appear on pages 361-375.

VII. A comparison of analyses of brands for five years shows in some cases essential evenness and in others considerable variation in composition. The tables showing composition for five years should prove helpful to the early buyer of mixed goods. Pages 376-386.

VIII. A summary of the article on limes and liming—pages 387-436—appears on page 436.

IX. The bulletin is well indexed on pages 437-440.

II. INTRODUCTION

The fertilizer law enacted in 1902 provides that the yearly bulletins of the Station dealing with commercial fertilizers shall not only give the results of the analyses of these goods, but shall also publish "additional information in relation to [their] character, composition, value and use." It further directs that publication be made "as promptly as the progress of the analyses will allow and as frequently as time and means permit." Usually two bulletins are issued each spring, in April and in June or July. The first gives the analyses of about 60 brands, the valuation schedule, a discussion of its use, a table of analyses for five years, etc. The second discloses the analyses of all the brands collected, shows their composition during the past five years, contains a general review of the trade of the State, makes statements as to the quantity and quality of the plant food sold in the sundry brands, considers the comparative values of the average goods of the current and preceding years, and outlines the relationship between selling prices and valuations.

These general matters are annually reviewed. In addition thereto, in the second and larger bulletin, there is yearly presented a somewhat full discussion of some special topic having to do with fertilization, a "feature" as it were. This plan was inaugurated in 1902, and presumably will be pursued for several years to come. Thus the recipient of the bulletins who preserves them will in time possess a more or less complete treatise on the general subject of fertilization.

So far as possible technicalities have been, are and will be avoided and plain every-day language used. Yet many who read will find that careful attention will be needed. For the assistance of such, glossaries of definitions were supplied in bulletins 99, 130, 143, and 152. These glossaries will be added to from time to time in the future. Anyone failing to grasp the meaning of the terms used should get bulletins 99, 130, 143 or 154 (if in print) and make use of their glossaries. They are free for the asking. The larger bulletin is always thoroughly indexed.

The following statement outlines the "features" of the preceding bulletins. The table of contents on pages 299-301 serves to introduce the reader to the matter contained in this issue.

Bulletin 93 (1902). *Formulas for home mixing.*—56 pages). (Out of print).

Bulletin 99 (1903). *Vermont's usage of fertilizers. Concerning fertilizer buying. Deficient plant food.*—(88 pages).

Bulletin 108 (1904). *Classification of commercial fertilizers sold in Vermont. Farm manures.*—(68 pages).

Bulletin 116 (1905). *How, when and what to use.*—(104 pages). (Out of print).

Bulletin 123 (1906). *Concerning the purchase of plant food. The moisture relations of the soil.*—(68 pages). (Out of print).

Bulletin 130 (1907). *Soil biology in its relation to fertilization.*—(144 pages). (Out of print).

Bulletin 135 (1908). *A quarter of a century of fertilizer inspection. Soil deterioration and soil humus.*—(128 pages).

Bulletin 143 (1909). *The service of a fertilizer control. Soil physiography.*—(144 pages). (Available only as a loan).

Bulletin 154 (1910). *Soil classifications and adaptations.*—(112 pages).

These articles were written in 1902, 1903, 1904, 1905, 1906, 1907, 1908, 1909 and 1910; but they are just as applicable to the purchase and use of fertilizers in 1911 and in succeeding years as they were when first penned. The reader of this bulletin who does not own a 99, a 108, a 135 or a 154, and wants either or all of them, has but to ask to receive. Nos. 93, 116, 123 and 130 are out of print. No. 143, being nearly exhausted, is only issued on loan to those who will promise to return it after it has served their purpose. Circular No. 1—free for the asking—outlines all these bulletins except Nos. 143 and 154. Circular 7 on "Plant Food Combinations for Sundry Crops" contains a reprint of the more important formulas, etc., originally issued in bulletin 116.

THE FERTILIZER LAW (CHAPTER 213 P. S.)

The term "commercial fertilizer" is defined to mean "compounds and manufactured substances containing * * * two or more of the ingredients" (nitrogen, potash, phosphoric acid) but not "the separate ingredients used to manufacture the same, or * * * bone meal, land plaster, lime or a substance the product of nature which is not compounded." (Sec. 4973 P. S.)

It provides that "every lot * * * of commercial fertilizer * * * shall be accompanied by a * * * statement * * * certifying the number of net pounds, * * * the * * * brand, * * * the name and address of the manufacturer, * * * and a chemical analysis stating the minimum percentages of nitrogen, of potash soluble in distilled water, and of soluble, reverted, insoluble, available and total phosphoric acids, and the maximum percentage of chlorin." (Sec. 4976 P. S.)

It provides that the "manufacturer, importer, agent or seller" (the latter only in case the manufacturer fails to comply with the law) "* * * shall annually * * * pay * * * a license fee of twenty dollars," which will permit "the sale of one brand of commercial fertilizer which shall be the product of the licensee." It further provides that "if a manufacturer * * * desires to sell * * * more than one brand, he shall annually * * * pay a license fee of twenty dollars for each * * * brand * * * in excess of one." "The fee(s) * * * cover and authorize sales * * * for the calendar year." (Secs. 4977-4978 P. S. as amended by No. 169 of the Acts of 1910).

It provides that any person offering unguaranteed, over-guaranteed or unlicensed goods shall be subject to a fine (Sec. 4981 P. S.); forbids the use of "leather or its products, hair, wool waste, garbage tankage or inert nitrogenous material" unless explicit notice thereof be made (Sec. 4980 P. S.); provides that license fees be sent to the state treasurer, and for the reimbursement of the Experiment station for expenses incurred (Sec. 4982 P. S.); for sampling, analyses and publication (Secs. 4990 and 4991 P. S.) forbids interference (Sec. 4993 P. S.);

and prescribes the procedure in case of violation (Sec. 4989 P. S.). The act does "not apply to persons manufacturing, importing or purchasing * * * fertilizers * * * for their own use and not for sale in this State." (Sec. 4992 P. S.).

The full text of the law will be furnished on application.

LIST OF LICENSEES

The following companies have paid licenses as required by law on the brands shown in the statement on pages 353-359 and in the tables on pages 361-375. The sale within the State of these brands, and of these brands only, is legal. All local agents, as well as intending purchasers, are warned against the handling of other brands, unless bought for personal use and not for sale. They are likewise warned against the sale of mixed goods of companies other than those listed herewith, since they render themselves liable to pay the twenty dollars license fee. "Parties manufacturing, importing or purchasing fertilizers for their own use and not for sale in this State" are not affected by the restrictions of the law.

American Agricultural Chemical Co., 2 Rector St., New York.
N. Y.

Armour Fertilizer Works, 930-938 Equitable Building, Baltimore, Md.

Bowker Fertilizer Co., 43 Chatham St., Boston, Mass.

J. F. Bromley, Granville, N. Y.

Buffalo Fertilizer Co., William St., near city line, Buffalo, N. Y.

Burlington Rendering Co., North Ave., Burlington, Vt.

Coe-Mortimer Co., 51 Chambers St., New York, N. Y.

Essex Fertilizer Co., 39 No. Market St., Boston, Mass.

Lister's Agricultural Chemical Works, Newark, N. J.

Lowell Fertilizer Co., 44 No. Market St., Boston, Mass.

New England Fertilizer Co., 42 No. Market St., Boston, Mass.

Parmenter & Polsey Fertilizer Co., 40 No. Market St., Boston, Mass.

Rogers & Hubbard Co., Middletown, Conn.

Sanderson Fertilizer and Chemical Co., New Haven, Conn.

COLLECTION OF SAMPLES

The sampling agents of the Station visited 77 towns and villages in Vermont during the spring of 1911 and drew 273 samples from dealers' stocks, representing 157 distinct brands, the output of the 14 companies licensed to sell in Vermont. A sample was secured of every brand which was licensed, save the the following:

Buffalo Fertilizer Co.: Fish Guano.

Lister's Agricultural Chemical Works: Grass and Oats Fertilizer.

Lowell (Swift's) Fertilizer Co.: Potato Grower.

New England Fertilizer Co.: Potato Grower.

SCHEDULE OF TRADE VALUES

The following schedule of trade values to be used in this State in 1911 is the one agreed upon by the Experiment stations of New England and New Jersey, after a careful study of prices ruling in the larger markets. The 1910 schedule is also shown for the purposes of comparison.

TRADE VALUES OF FERTILIZING INGREDIENTS IN RAW MATERIALS AND CHEMICALS FOR 1910 AND 1911

	1910	1911
	cts. per lb.	cts. per lb.
Nitrogen in nitrates	16	16
Nitrogen in ammonia salts	16	16
Organic nitrogen in dry and fine ground fish, blood and meat	20	23
" " in fine ground bone and tankage and in mixed fertilizers.....	20	20
" " in coarse bone and tankage....	15	15
Phosphoric acid soluble in water.....	4½	4½
" " soluble in ammonium citrate¹ ...	4	4
" " in fine ground bone and tankage.	4	4
" " in coarse bone and tankage.....	3½	3½
" " insoluble (in water and in ammonium citrate¹) in mixed fertilizers	2	2
Potash as high grade sulphate and in mixtures free from muriate (chlorid)	5	5
Potash as muriate	4¼	4¼

¹ Dissolved from 2 grams of the prepared sample, previously extracted with pure water, by 100 c. c. of a neutral solution of ammonium citrate, sp. gr. 1.09, in 30 minutes at 65 degrees C, with agitation once in five minutes.

These trade values are, as nearly as can be estimated, the average figures at which, in the six months preceding March 1st, the respective ingredients could be bought at retail for cash in the larger markets (Boston, New York, etc.), in the *raw materials*, unmixed. They also correspond to the average wholesale prices for six months ending March 1st, plus about 20 percent in the case of goods for which there are wholesale quotations. The valuations obtained by the use of the above figures will be found to agree fairly with the reasonable average retail price in the large markets of standard raw materials.

In applying trade values to mixed goods, organic nitrogen is valued at 20 cents a pound; nitrogen as nitrate of soda and as sulphate of ammonia at 16 cents a pound; soluble, reverted and insoluble phosphoric acid at $4\frac{1}{2}$, 4 and 2 cents a pound respectively; and potash at $4\frac{1}{4}$ cents a pound, if there is sufficient chlorin to unite with all the potash; if not, it is valued at 5 cents.

A valuation is determined as follows: The percentages or pounds per hundred of each ingredient (i. e., nitrate nitrogen, ammoniacal nitrogen, organic nitrogen, soluble phosphoric acid, reverted phosphoric acid, insoluble phosphoric acid and potash), are multiplied by 20, giving the number of pounds of each ingredient in a ton. These figures are then multiplied by their respective pound prices.

THE MEANING OF COMMERCIAL VALUATIONS

That there may be no misconception and that the reader may clearly appreciate what these valuations are and what they are not, it is our custom to call attention repeatedly to the fact that *a station valuation does not represent the proper selling price of a fertilizer at the point of consumption*. Neither should it be inferred that the ingredients in the brand in question have of necessity the commercial value indicated. It may be greater or less than is shown. The Station does not pretend dogmatically to state what may be the commercial worth or valuation of any one of the many brands of fertilizer sold in the Vermont market, as it cannot always affirm the quality of the crude stock used,

particularly the nitrogenous material, although in a better position to do this today than ever before. The valuation system is based on the assumption that all brands are composed solely of high grade ingredients, an assumption which is probably erroneous. "Valuations" should not be construed as showing the commercial worth of a given fertilizer, but the *retail trade value or cash-cost of amounts of nitrogen, phosphoric acid and potash, equal to those contained in a ton of the brand in question, in unmixed, standard raw materials of good quality, at the seaboard.* They bear no necessary relationship to the agricultural or the crop producing value of the goods, but simply indicate the current market prices of standard commercial articles, more particularly nitrate of soda, sulphate of ammonia, dried blood, tankage, ground bone, acid phosphate, muriate of potash, sulphate of potash and kainit.

Valuations thus construed, while not infallible, are helpful:

(a) To show whether a given fertilizer is worth its cost from the *commercial* standpoint.

(b) As a common basis on which to compare the *commercial* values of different brands, enabling buyers to note whether prices asked are warranted by values contained.

Valuations, then, simply show the cost of ready-made plant food. Its cost, however, is but one of the many charges which determine the retail cost of commercial fertilizers, just as the leather from which a pair of shoes is made is but one of the many charges which go to make up the retail cost thereof. The plant food must be also mixed, stored, reground, bagged, loaded, and freighted. Then, too, commissions to agents and dealers, the expense of selling on long credit, the item of bad debts, the interest on investments, the depreciation of the manufacturing plant, profits, etc., are also proper and fixed charges; yet not one of these so-called "overhead charges" contributes to plant growth. Commercial fertilizers are usually applied in the mixed form, but this is simply a matter of convenience, for as good

results may be obtained by the separate application of the crude ingredients.

An illustration may serve to make these statements more clear. A farmer buys in Boston or New York 50 pounds of nitrate of soda, 350 pounds of dried blood, 1,475 pounds of acid phosphate, and 125 pounds of muriate of potash, and he mixes these ingredients together at home on his barn floor, as thousands have done before him. The cost of this ton after mixing will be made up as follows: (a) Cost of material in the market; (b) cost of transportation; (c) cost of mixing. The first item (a) entering into the total cost is the only one included in the "valuation." If to (a) be added (b), (c), and, also, the expenses of selling through agents, long credits, bad debts, etc., we have the factors involved in the cost of fertilizers delivered in Vermont. Clearly the local selling price must of necessity exceed the "valuation." Since the cost of mixing and selling varies with different companies, and since freight rates to the different sections of the State are unlike, no arbitrary sum to cover these charges can be assigned. These can be estimated best by the consumer to fit his local conditions. He should expect to pay and does pay not only for the plant food contents of his purchase, but also a fair margin to cover the expenses incident to assemblage, manufacture and sale, as well as for the convenience and other advantages pertaining to the use of ready-made and locally supplied plant food. If the selling price does not exceed the valuation by more than 35 or 40 percent it may not be too high, but in proportion as the excess increases beyond this point there is reason to question the economy of the purchase. The reader is referred for a further and somewhat full discussion of this matter to pages 340-345 of this bulletin, also to the special article in bulletin 143, pages 183-192, dealing with the exposition of the meaning of the analyses and valuations.

III. RESULTS OF FERTILIZER INSPECTION

I. AS TO QUANTITY OF PLANT FOOD

(a) COMPARISON OF GUARANTIES AND ANALYSES

The general quality of the brands sold in 1911 was better than in any previous year save 1903. Only 11 of the 157 brands analyzed were found wanting in any respect, and four of this number were barely over the line, being but very slightly short in a single ingredient. Only 2 brands failed to furnish a commercial equivalent of the guaranties made for them by their manufacturers, and the money shortages in these cases were only 13 or 14 cents respectively per ton. Last year's inspection also proved very satisfactory, their being but 14 brands which were deficient, and none seriously so. Such a statement is a most gratifying one to make at a time when larger numbers of brands than hitherto have been sold. The situation is in strong contrast with that obtaining three years ago, when nearly one brand in three was lacking in some respect; when six brands failed to furnish a commercial equivalent of the plant food promises made for them; and when a case was reported to a state's attorney for prosecution.

The plant food shortages in deficient brands were distributed as follows: Nitrogen, 1; available phosphoric acid, 3; potash, 7. Of the 461 guaranties made on 157 brands by the 14 manufacturers, only 4 guaranties, or but 1 in 115, were lacking to an extent greater than 0.50 percent of a single ingredient; and but 2 were lacking to an extent greater than 0.75 percent. A better result could hardly be desired.

Whenever guaranties were not made good the analytical work was repeated, and, invariably recourse was had to other samples, taken a second time from the original shipments, except in cases where the goods were used prior to the determination of the shortage. In several cases when results seemed open to question, other samples elsewhere drawn were analyzed. Unusually high figures were similarly checked. Careful compari-

sons with the analytical results of previous years were also instituted with a view of minimizing error and standardizing results. This general procedure has been in vogue at this Station for years, and is thought to minimize to the last degree the likelihood of error in sampling or analysis.

The condensed results of 17 years' inspection of the Vermont fertilizer trade, so far as they relate to the maintenance of guaranty, follow:

Year	Number of brands analyzed	Number of brands up to or above guaranty throughout	Number of brands deficient	Percent of total number up to or above guaranty	Percent of total number affording commercial equivalent of guaranty
1895	92	76	16	83	95
1896	110	91	19	83	99
1897	134	113	21	84	94
1898	126	113	13	90	100
1899	137	105	32	77	90
1900	132	114	18	86	96
1901	134	118	16	87	99
1902	136	123	13	90	100
1903	111	106	5	96	100
1904	118	94	24	80	97
1905	130	92	38	71	94
1906	130	110	20	85	98
1907	129	99	30	77	94
1908	130	92	38	71	95
1909	133	111	22	83	96
1910	152	138	14	91	100
1911	157	146	11	93	99

The table on the next page shows the number of brands sold by the different companies licensed in the State, the number of guaranties (nitrogen, available phosphoric acid, potash) made by each, and the number of failures to make the same good within 0.10 percent of nitrogen or 0.20 percent of available phosphoric acid or potash.

Seven of the fourteen companies contribute brands to the delinquent list. Three furnish a single brand each, and four, two apiece.

MAINTENANCE OF GUARANTIES BY LICENSEES

Name of company	Number of brands	Number of guaranties	Number of guaranties not made good	Number of brands not making good the commercial equivalent of the guaranty
American Agricultural Chemical Co.....	5	13	0	0
Bradley Fertilizer Co. branch.....	12	35	0	0
Clark's Cove Fertilizer Co. branch.....	3	9	0	0
Cleveland Dryer Co. branch.....	3	9	0	0
Crocker Fert. and Chem. Co. branch...	4	12	0	0
Cumberland Bone Phosphate Co. branch	3	9	0	0
L. B. Darling Co. branch.....	2	6	0	0
East India Chemical Co. branch.....	3	9	0	0
Great Eastern Fertilizer Co. branch...	4	12	0	0
Pacific Guano Co. branch.....	3	9	0	0
Quinnipiac Co. branch	4	12	0	0
Read Fertilizer Co. branch.....	7	20	1	0
Henry F. Tucker Co. branch.....	3	9	0	0
Williams & Clark Fertilizer Co. branch.	7	21	0	0
American Agricultural Chem. Co.—Total	63	185	1	0
Armour Fertilizer Works.....	5	14	2	0
Bowker Fertilizer Co.	17	49	1	1
J. F. Bromley	7	20	1	0
Buffalo Fertilizer Co.	6	16	2	0
Burlington Rendering Co.	2	6	0	0
Coe-Mortimer Co.	8	23	2	1
Essex Fertilizer Co.	6	18	0	0
Lister's Agricultural Chemical Works....	8	23	0	0
Lowell Fertilizer Co.	10	30	2	0
New England Fertilizer Co.	6	18	0	0
Parmenter and Polsey Fertilizer Co.....	6	18	0	0
Rogers and Hubbard Co.	8	24	0	0
Sanderson Fertilizer and Chemical Co....	5	15	0	0
Total.....	157	459	11	2

The range of composition and the closeness with which guaranties are met are shown in the first table on the next page. The condition of affairs it discloses, a close hugging of the guaranties, has obtained for years, as appears in the second table, which shows the excess of the average analysis over the average guaranty for five years. The manufacturers naturally do not mean to place more plant food than is absolutely necessary in their goods, which carry on the average rather less than

ten percent excess over the minimum guaranty. Maximum guaranties, of course, are quite meaningless.

GUARANTIES, ANALYSES, SELLING PRICES AND VALUATIONS

	PERCENT GUARANTIED			PERCENT FOUND			Excess of average analysis over guaranty
	Lowest	Highest	Average	Lowest	Highest	Average	
Nitrogen,	0.8*	8.5	†2.03	0.86	8.51	2.23	0.20
Total phosphoric acid,	5.	16.	8.69	5.68	15.79	9.85	1.16
Avail. phosphoric acid,	4.	11.	7.56	4.70	11.06	8.29	0.73
Potash,	1.	10.	4.68	1.07	11.81	4.94	0.26
Selling price,	\$22.50	\$59.00	\$31.45	.....	.....	.....	.....
Valuation,	\$10.63	\$39.80	\$17.71	\$10.63	\$41.88	\$19.53	\$1.82

FIVE YEARS' COMPARISON OF THE EXCESS OF ANALYSIS OVER GUARANTIES

	1907	1908	1909	1910	1911	Avg'e for 5 years
Nitrogen,	0.20	0.18	0.22	0.29	0.20	0.22
Total phosphoric acid,	1.21	1.24	1.39	0.83	1.16	1.17
Avail. phosphoric acid,	0.45	0.50	0.59	0.80	0.73	0.61
Potash,	0.35	0.33	0.33	0.33	0.26	0.32
Valuation,	\$1.61	\$1.69	\$1.86	\$1.46	\$1.82	\$1.68

*No nitrogen in 12 brands.

†Non-nitrogenous goods omitted; if included, average drops 0.16 percent in guaranties and 0.17 percent in actualities.

While the above statement shows that the goods compare well on the average with the claims made for them, the tables on pages 361-375, as well as the statements on page 311 and 313, betrays the fact that within this average lie concealed a few small deficiencies. It is but scant satisfaction to the buyer of a brand in which the amount of plant food guaranteed is not furnished to know that the "average" is good. It is for him to exercise care and to avoid buying such goods. Yet it should be said that this year no *seriously* faulty fertilizers, so far as guaranty maintenance is concerned, were found. Some years, however, very deficient goods have been offered.

(b) COMPARATIVE VALUES OF FERTILIZERS OF 1910 AND 1911

Of the 157 brands of commercial fertilizers which were sampled by the Station during 1910 and 1911, 150 have been selected for comparison of the characters of the goods sold under these brands in each of the two years. Only those brands have been chosen which have been sampled both years. The comparison shows a loss in all three ingredients in 1911 as compared with 1910, the net decrease on a money basis, i. e., valuation, being 46 cents, or $2\frac{1}{2}$ percent of the money value. In other words the average goods this year are slightly poorer in quality than were the average goods last year. However, since guaranties were practically always maintained each year, there is no reason to cavil at this lessening of what is essentially a gratuity on the part of the manufacturers, who are not required to furnish more than their minimum guaranties.

AVERAGE COMPOSITION OF FERTILIZERS IN 1910 AND 1911

Name of Ingredient	1910		1911	
	Pounds in a hundred	Valuation at 1911 prices	Pounds in a hundred	Valuation at 1911 prices
Nitrogen *	2.13	\$7.67	2.05	\$7.38
Soluble phosphoric acid	5.52	4.97	5.68	5.11
Reverted phosphoric acid	2.83	2.26	2.61	2.09
Insoluble phosphoric acid	1.53	0.61	1.57	0.63
Total phosphoric acid	9.88	....	9.86	....
Available phosphoric acid	8.35	....	8.29	....
Potash *	5.01	4.26	4.82	4.10
Total valuation per ton..		\$19.77		\$19.31

*Nitrogen calculated as $\frac{1}{2}$ mineral, $\frac{1}{2}$ organic; potash calculated as muriate.

(c) COMPARATIVE VALUE OF FERTILIZERS FROM 1895 TO 1911

The next table shows the average composition of the fertilizers as analyzed during the past 17 years. Every brand tested each year is included in the comparison, each one being given equal value. It is well understood that this is not strictly a correct method of calculation, but it is the best which can be done in the absence of data showing the consumption of individual brands. Inasmuch as high grade goods in the past sold slowly, and, unfortunately, low grade brands as a rule readily, the actual average as used is probably somewhat lower than that shown in the table. Yet the evidence in hand indicates a lessened usage of low and a larger usage of medium and high grades.

It ought to be remarked at this point that neither this table, nor the table which immediately precedes it, nor the discussion of this matter, should be construed too literally, for the reasons cited as to the usage of the several brands. Some attempt was made in 1904 to estimate the relative usage of the different grades, but without much success. No data is available that is trustworthy, while if one appeals to the individual judgment of those who are in closest touch with the trade, the inevitable personal equation enters to a large extent. The result of such an inquiry therefore seems so largely a matter of guesswork as to be hardly worth recording. The writer's judgment would place the average goods as actually used at 1.80 to 1.90 percent nitrogen, 8.50 percent available phosphoric acid, and 3.25 to 3.50 percent potash. The relatively larger usage of the low and medium grades and smaller usage of the higher grades which doubtless obtains, tends to lower the general average. But there is evidence tending to show yearly an increase in the usage of the higher grades, a tendency which on the whole is to be encouraged.

The average commercial fertilizer sold in Vermont in 1911 contains less of each form of plant food than the average 1910 goods, the same nitrogen and phosphoric acid contents as have been found for the past five years, and 0.30 percent more potash.

AVERAGE COMPOSITION OF FERTILIZERS SOLD IN VERMONT FROM 1895 TO 1911¹

Year	Number of brands	Nitrogen	Soluble phosphoric acid	Reverted phosphoric acid	Insoluble phosphoric acid	Total phosphoric acid	Available phosphoric acid	Potash
1895	92	2.22	5.84	2.56	2.23	10.63	8.40	3.46
1896	110	2.22	5.36	3.44	2.23	11.03	8.80	3.66
1897	134	2.12	5.34	3.68	2.23	11.25	9.02	3.43
1898	126	2.21	5.51	3.32	2.08	10.91	8.83	3.81
1899	137	2.06	5.08	3.32	2.26	10.66	8.40	4.10
1900	132	2.08	5.29	3.26	2.58	11.13	8.55	3.80
1901	134	2.08	5.34	3.23	2.41	10.98	8.57	4.33
1902	136	2.22	5.56	3.06	2.39	11.01	8.62	4.21
1903	111	2.02	5.13	3.42	2.50	11.05	8.55	3.97
1904	118	1.98	5.20	3.19	2.38	10.77	8.39	3.95
1905	130	2.03	4.63	3.63	2.63	10.89	8.26	4.18
1906	130	2.09	4.70	3.65	2.63	10.98	8.35	4.37
1907	129	2.16	4.40	3.60	2.40	10.40	8.00	4.65
1908	130	2.05	4.64	3.50	2.29	10.43	8.14	4.58
1909	133	2.08	5.25	3.07	2.21	10.53	8.32	4.70
1910	152	2.12	5.50	2.86	1.53	9.89	8.36	4.99
1911	157	2.06	5.69	2.60	1.56	9.85	8.29	4.94

AVERAGE COST OF FERTILIZERS SOLD IN VERMONT FROM 1895 TO 1911¹

Year	Number of brands analyzed	Average selling price per ton	Average valuation at each year's trade values	Excess of selling price over valuation	Percentage excess of selling price over valuation	Value of plant food received for each dollar paid out	Average valuation at 1911 trade values
1895	92	\$30.90	\$21.28	\$ 9.62	45	69 cts.	\$19.13
1896	110	30.90	19.73	11.17	57	64 "	19.56
1897	134	29.19	19.47	9.72	50	67 "	19.19
1898	126	29.04	17.86	11.18	63	61 "	19.65
1899	137	28.75	17.39	11.36	65	60 "	19.04
1900	132	28.73	18.08	10.65	59	63 "	18.93
1901	134	28.75	19.44	9.31	48	68 "	19.52
1902	136	28.23	20.18	8.05	40	71 "	19.98
1903	111	28.25	18.59	9.66	52	66 "	19.00
1904	118	29.00	18.47	10.53	57	64 "	18.67
1905	130	29.62	19.04	10.58	56	64 "	18.98
1906	130	29.52	19.38	10.14	52	66 "	19.43
1907	129	30.57	21.21	9.36	45	69 "	19.53
1908	130	31.24	20.75	10.49	51	66 "	19.17
1909	133	31.43	18.84	12.59	67	60 "	19.56
1910	152	31.45	20.57	10.88	53	65 "	19.83
1911	157	31.41	19.53	11.88	61	52 "	19.53

¹See statement as to average midway down opposite page.

The increase in the average of the past seven years as compared with those of previous years, is due to the high grade of certain goods sold for the first time in 1905, and to the entry in each of several years since of a number of relatively high grade goods. A survey of the table indicates that no profound change has taken place during the fifteen years. Indeed, there seems to be three periods of four, six and seven years respectively wherein there are somewhat wide variations in the plant food contents of the average goods, particularly in phosphoric acid and potash, as shown below:

1895-98....nitrogen	2.19,	available phosphoric acid	8.75,	potash	3.60
1899-04....nitrogen	2.07,	available phosphoric acid	8.51,	potash	4.06
1905-11....nitrogen	2.08,	available phosphoric acid	8.25,	potash	4.63

The average grade goods are better today than hitherto; but that is not saying that there are not many inferior ones on the market.

COST OF PLANT FOOD IN THE AVERAGE MIXED FERTILIZER, 1895 TO 1911

Year	Number of brands analyzed	Cost of one pound of organic nitrogen	Cost of one pound of available phosphoric acid	Cost of one pound of potash (as muriate)
1895	92	23.9 cts.	8.7 cts.	6.5 cts.
1896	110	22.0 "	8.6 "	7.1 "
1897	134	21.0 "	8.3 "	6.8 "
1898	126	22.8 "	7.3 "	6.9 "
1899	137	23.1 "	7.4 "	7.0 "
1900	132	24.6 "	7.1 "	6.7 "
1901	134	23.7 "	7.4 "	6.3 "
1902	136	23.1 "	7.0 "	6.0 "
1903	111	25.9 "	6.8 "	6.5 "
1904	118	27.5 "	6.9 "	6.7 "
1905	130	28.9 "	6.8 "	6.6 "
1906	130	28.3 "	6.6 "	6.4 "
1907	129	29.6 "	6.9 "	6.1 "
1908	130	30.6 "	7.1 "	6.3 "
1909	133	31.7 "	6.3 "	7.1 "
1910*	152	30.6 "	6.6 "	6.5 "
1911	157	32.2 "	7.0 "	6.8 "

*1910 figures as published in Bul. 154 were slightly incorrect, owing to error in calculation.

At what prices did the sundry forms of available plant food sell in the average mixed fertilizer of these years? These data are afforded by the table shown on the opposite page, from which it is evident that the tendency of late years has been towards increased selling prices. This is particularly true of medium and of high grade goods.

2. AS TO QUALITY OF PLANT FOOD

(a) SOURCES OF PLANT FOOD IN LICENSED FERTILIZERS

The table on page 314 as well as those on pages 361-375 show wide ranges in composition, amounts of nitrogen varying from 0.86 to 8.51 percent, of available phosphoric acid from 4.70 to 11.06 percent, and of potash from 1.07 to 11.81 percent. These figures alone, however, do not tell the whole story as to the character of the ingredients used, a matter of quite as much importance as their amounts. A further scrutiny into the details of the sundry analyses throws some light on the sources whence the plant food purveyed in the various brands is derived.

NITROGEN

In all but 6 of the 145 brands carrying nitrogen, more or less of the mineral forms thereof was found to be present. Some of the 14 manufacturers selling in Vermont have in the past habitually used nitrate of soda or sulphate of ammonia as a means of supplying nitrogen; others have just begun to use mineral forms of nitrogen. Doubtless the fact that mineral nitrogen is far cheaper today than is organic nitrogen explains its present freer usage. Time was, not long ago, when the ratio of mineral to organic nitrogen was much less than it is today in the goods sold in Vermont and when a large share of the goods contained neither nitrate nor ammonia salts. The amounts found in this year's goods vary from 0.11 to 7.58 percent, averaging 1.04 percent or 47 percent of the total nitrogen present in the brands carrying this ingredient. In 13 of these brands the amounts of mineral nitrogen present were very small, but in the residue the amounts were readily measurable. Under certain circumstances

and for certain purposes mineral nitrogen, particularly in the nitrate form, is to be preferred agriculturally to organic nitrogen. Under other circumstances it is not as much to be desired. It is more readily available but is more easily lost by leaching (see pages 89 to 90 of bulletin 99). Speaking broadly, however, the presence of mineral nitrogen in commercial fertilizers is to be favored for most of the purposes for which such goods are used in Vermont.

All the brands which carry nitrogen contain more or less organic nitrogen, derived doubtless as a rule from standard animal and vegetable ammoniates, such as dried blood, meat meal, fish scrap, tankage, etc. Probably tankage is at present its main source in a large proportion of the brands.

For the first time in its history, or in that of any other fertilizer control in this section of the country, this Station, joining with its sister stations in the North Atlantic states, prints in its table of analyses tabulated data as to the character of the organic nitrogen used in the various brands offered for sale, with a view of indicating its serviceability in crop growth. This station for more than a dozen years has thus "kept tab" on the several fertilizers offered for sale. It has formed an opinion in many cases of the character of the nitrogen used therein. It has not hesitated by correspondence and by personal interview to question the character of the organic nitrogen used in certain brands, and has in times past not infrequently found its queries to be justified by the facts, either directly acknowledged, or at least not gainsaid, by the manufacturers. Its long experience with the alkaline permanganate method of determining organic nitrogen availability, the long series of analytical results accumulated in its files during the past dozen years, the work done by other stations in its section of the country using the same method, have served to give it confidence in the essential accuracy of its findings. But it has not hitherto deemed itself justified in publishing the results as applied to the separate brands of goods as found on sale. However, at a meeting of the directors of the

Experiment stations of the North Atlantic states (other than Pennsylvania) held in Boston, Mass., in March, 1910, the entire situation as to the quality of the organic nitrogen used in the commercial fertilizers sold in that territory was canvassed, the crying need of an adequate discriminatory method was universally acknowledged, and a committee was appointed, consisting of the chemists of the Rhode Island, Connecticut (State) and Vermont stations, the latter as chairman, still further to investigate the applicability of chemical methods to the determination of organic nitrogen availability, the same to report if practicable at a similar meeting to be held in March, 1911 a method to be used by the fertilizer controls of the states there represented. All the manufacturers selling goods in the territory of the North Atlantic states, (other than Pennsylvania) were at once notified of the expectation of the several controls to employ some such method in the inspection of 1911. As a consequence of this action and of a large amount of cooperative work accomplished by the committee, including highly satisfactory confirmatory vegetation trials made in Rhode Island, the alkaline permanganate method, somewhat modified both from its earlier form¹ and also modified yet again from that used by this Station last year², has been adopted, as well as a standard form of stating results as shown in the tables on pages 361 to 375; and all the manufacturers interested were at once informed as to both.

The nitrogen content of all commercial fertilizers as sold in the North Atlantic states, (other than Pennsylvania) is now to be stated, if deemed practicable by the official in charge of the control, in the following terms:

1. Nitrogen in nitrates.
2. Nitrogen in ammonia salts.
3. Water soluble organic nitrogen.
4. Active water insoluble organic nitrogen.
5. Inactive water insoluble organic nitrogen.
6. Total nitrogen found.
7. Total nitrogen guaranteed.

¹ Vt. Sta. Rpts. 11, pp. 160-171 (1898); 12, pp. 137-139 (1899); 14, pp. 210-221 (1901).

² Vt. Sta. Bul. 154, p. 656 (1910).

In order that the reader may clearly understand just what is meant by this phraseology the following explanatory notes are offered:

1. *Nitrogen in nitrates.* The data in this column indicates the percentage of nitrogen found to be present which is derived from nitrate of soda, a mineral form of nitrogen which is soluble in water and immediately available to plant growth.

2. *Nitrogen in ammonia salts.* The data in this column indicates the percentage of nitrogen derived from sulphate of ammonia, a gas house by-product of high grade.¹ It is a mineral form of nitrogen which is soluble in water and readily available to plant growth.

3. *Water soluble organic nitrogen.* The data in this column indicates the percentage of nitrogen derived from organic sources which is soluble in water.¹ The presumption is that most organic nitrogen soluble in water is likely on that account to be relatively available to plant growth.

4. *Active water insoluble organic nitrogen.* The data in this column indicates the percentage of such organic nitrogen as is not soluble in water, but, notwithstanding, is deemed to be relatively available to plant growth, this judgment being based upon the relative readiness with which it has been acted upon by the chemicals used in the modified alkaline permanganate method as well as upon extensive vegetation trials.

5. *Inactive water insoluble organic nitrogen.* The data in this column shows the percentage of the water insoluble organic nitrogen that has not been acted upon by the chemicals used in the modified alkaline permanganate process. It is considered less available to plant growth than are those forms which are scheduled under the other heads.

In order that the significance of the data appearing this year for the first time in the analytical tables may be the more clearly understood, the sets of hypothetical figures shown on the opposite page are submitted:

¹The nitrogen derived from calcium cyanamid would appear in either or both—usually both—of these places, according to circumstances.

Quality of organic nitrogen	Nitrogen in nitrates	Nitrogen in ammonia salts	Water soluble organic nitrogen	Active water insoluble organic nitrogen	Inactive water insoluble organic nitrogen	Total nitrogen found
A. Good,	0.11	0.21	0.27	0.53	0.25	1.37
B. Good,	0.57	1.40	0.27	0.69	0.32	3.25
C. Somewhat questionable,	0.10	0.70	0.20	0.35	0.35	1.70
D. Inferior,	1.00	0.10	0.15	0.25	0.45	1.95
E. Inferior,	0.80	1.10	0.10	0.20	0.30	2.50

Why are A and B good? Why are D and E inferior? Why should one list A as "good" when it contains only about half as much total nitrogen as does E which is listed as inferior? Would on this account A be a better purchase than E? Of course in the purchase of commercial fertilizers a number of different considerations have to be taken into account. However in this discussion of organic nitrogen availability just one thing is being kept in mind, *the quality*, not the quantity, of the organic nitrogen used. It is a question of character rather than of amount; of the nature of the organic nitrogen used rather than of the total nitrogen content. The state law very properly forbids the use of inferior forms of organic nitrogen unless their use is declared on each package. The fact moreover that the mineral nitrogen contents of D and E are large, and that, of course, such nitrogens are readily available, has no bearing upon the particular matter now under consideration. In other words, that is not the point. The organic nitrogens used in the manufacture of D and E are relatively inferior. One should note concerning the hypothetical figures:

A. That only 0.25 percent out of 1.05 percent of the organic nitrogen is classed as being relatively inactive and only 0.25 out of 0.78 of the water insoluble organic nitrogen is thus classified.

B. That only 0.32 percent out of 1.28 and 0.32 out of 1.01 is thus classified.

C. That 0.35 percent out of 0.90 and 0.35 out of 0.70 is thus classified.

D. That 0.45 percent out of 0.85 and 0.45 out of 0.70 is thus classified.

E. That 0.30 percent out of 0.60 and 0.30 out of 0.50 is thus classified.

Comparing these figures on the hundred percent basis one finds in the better goods 24 and 25 percent of the nitrogen classified as relatively inactive; in the poorer goods 49 and 50 percent; and of the water insoluble nitrogen in the better goods 31 and 32 percent is classified as inactive; in the poorer goods 65 and 60 percent. It is the relativity of the figures rather than the absolute figures which determines matters.

Now as to the specific cases developed in this year's inspection. There appears to be no reason to cavil at the results afforded by the analyses of the goods sold by ten of the fourteen companies licensed in Vermont, although in a few cases certain brands approach somewhat near the danger line. Attention is called however to the relatively high inactive water insoluble organic nitrogen contents as compared with the water soluble organic nitrogen and active water insoluble organic nitrogen contents of the following brands. There seems reason in each case to question the quality of the organic nitrogen used.

Armour Fertilizer Works, Baltimore, Md.: All brands carrying nitrogen offered for sale in Vermont, viz.:

Corn Special,
Complete Manure,
High Grade Potato,
General Farm Fertilizer.

J. F. Bromley, Granville, N. Y.: Three of the six nitrogen containing brands offered for sale in Vermont, viz.:

Special Potato Fertilizer,
Special Corn Fertilizer,
Corn and Potato.

Buffalo Fertilizer Co., Buffalo, N. Y.: One of the four nitrogen containing goods offered for sale in Vermont, viz.:

Farmer's Choice.

Coe-Mortimer Co., New York, N. Y.: Two of the seven nitrogen containing brands offered for sale in Vermont, viz.:

Special Potato and Fruit Grower.
Gold Brand Excelsior Guano.

Correspondence with the companies interested developed the following situation:

The Armour Fertilizer Works claim that "all our materials are purchased on a certain percentage guaranteed available nitrogen and in all cases this has been above the limit placed by the New England State Association." A further statement is made to the effect that "while such materials as acidulated garbage tankage may give low availability results with the alkaline-permanganate method, yet no one with a practical knowledge of the fertilizer business will seriously contend that acidulated garbage tankage should be excluded from commercial fertilizers (for the reason that) the demand for ammoniates is too heavy to permit such a ruling."

It may be said in this connection:

1. No "limit" has been placed by the fertilizer controls of the North Atlantic states. There is no "New England State Association."

2. The contention that commercial considerations should determine the character of the organic nitrogen used in a fertilizer is an interesting one, particularly to the farmer whose crops need available nitrogen.

J. F. Bromley's goods are made for him by the Armour Fertilizer Works. The latter make the identical claims for these brands that they make for those sold under their own name; and the statements appearing above naturally apply in the case of the Bromley goods as strongly as in the case of the Armour brands.

The Buffalo Fertilizer Company contends touching the character of the only brand in question that if it "uses an inert nitrogenous material as a filler instead of sand or something of that sort (it has) not violated the law in any way" provided the full guaranty of nitrogen is furnished in, say, sulphate of ammonia. For example, if 1% nitrogen is guaranteed and 1% is furnished in sulphate of ammonia, it claims that its use of a low grade nitrogenous material furnishing nitrogen in excess of its

guaranty is not a violation of the law. It claims that since 0.69% of the nitrogen in its Farmer's Choice brand was found in mineral forms or soluble in water as against an 0.8% guaranty "aside from the small deficiency of 0.11 percent we have fully complied with our guaranty from sources giving absolutely available nitrogen"; that "as long as we are up to the guaranty, we have fulfilled the law in every respect and that it does not make any difference what material is used as a filler."

The law reads as follows:

"Sec. 4980. *Prohibited materials in composition.* No person shall sell, offer or expose for sale leather or its products, hair, wool waste, garbage tankage or inert nitrogenous material, as a fertilizer or ingredient thereof, unless an explicit printed statement of the fact is conspicuously affixed to each package of such fertilizer, and accompanies each such parcel or lot of the same."

This calls for the statement upon the fertilizer sack of the use of inert nitrogenous material. The failure to state its use is what is claimed in this and other cases. A manufacturer may use it if he pleases to do so and as freely as he desires, provided he states its use. The fact, if it is a fact, that a manufacturer purveys the full guaranty of unimpeachable nitrogen does not permit him to introduce in addition thereto inert nitrogen into his goods, unless, in accordance with section 4980, he declares its presence on each package. The Buffalo Company states that "finely ground garbage tankage makes the best filler that we know of." The use of garbage tankage as a conditioner of fertilizers is not legal in Vermont unless declared upon each package. The company states that it will "avoid the use of any of this material in Vermont in the future."

The *Coe-Mortimer Co.* points out as to the Special Potato and Fruit Grower that it was found to contain 0.05 percent excess over total guaranty of mineral forms of nitrogen, of water soluble and of active water insoluble nitrogen. It claims that such inert nitrogen as is present is unobjectionable since it is in excess of

guaranty. The views of the Station upon this point were stated in the preceding paragraph. In regard to this brand and the Gold Brand Excelsior Guano, the company states that is used "ten percent ammonia drier" in part in the manufacture of the goods in question, the shipments having been traced. "Ten percent ammonia drier" is the trade name for the lower grade of calcium cyanamid, a new, valuable and presumably available form of nitrogen derived from the air. This contains a large proportion of peat added as a conditioner, dust reducer and diluent. The manufacturers of the cyanamid claim that their process renders available the inert nitrogen of the peat. The Coe-Mortimer Company, after it had used a considerable amount, found that this claim was not borne out in fact and discontinued its use, employing in its place a higher grade, 18 percent product, containing little or no peat and hence not open to this objection. There seems every reason to believe that the unfavorable results attained this year—and they are at worst not very bad—are due to the use of this material, which, as has already been remarked, was discontinued by the company in advance of the station's report and as a result of its own findings.

PHOSPHORIC ACID

Some companies furnish more total phosphoric acid in available form than do others; some, more of the water-soluble relative to the citrate-soluble or reverted than do others. Water-soluble phosphoric acid cannot be other than of the best grade and is to be preferred to that not thus soluble. Citrate-soluble phosphoric acid, while often, and perhaps usually, quite as good agriculturally as that which is soluble in water, may be of distinctly lower grade (agriculturally) if certain classes of phosphatic crude stock, such, for example, as ignited alumina phosphate, are used. Low soluble and high reverted phosphoric acid contents do not of necessity mean that the available phosphoric acid is not as valuable as when the conditions are reversed, but that the likelihood of this being true is lessened.

The proportions of the total phosphoric acid found in the various brands to be in available forms varied from 58 percent to 97 percent. The proportions of available phosphoric acid found to be in a water-soluble form varied from nil to 95 percent. Grouped according to their manufacture it was found that extremes for available in total were 69 and 90 percents, for water-soluble in available 31 and 81 percents. In others words, the average goods made by one firm carried 90 percent of the total phosphoric acid in available form, while those made by another firm furnished but 76 percent in that shape, the remainder ranging between. Similarly, on the average 81 percent of the available phosphoric acid furnished by one manufacturer was soluble in water, while only 31 percent was thus soluble in the average goods of another firm. The low availability seems to be due in some cases to the use of considerable quantities of incompletely dissolved bone or of bone meal. Whether in other cases it is due to this cause, to imperfectly cut phosphate rock, to the age of the goods, to the use of agriculturally inferior forms of phosphoric acid, or to other causes, does not always appear.

POTASH

This ingredient is sold in mixed goods in the form of muriate, sulphate, kainit, or, very rarely, nitrate. The direct or inferential claim is made for two-thirds of the brands that sulphate of potash is used in their manufacture. This is usually merely a subterfuge, is intentionally misleading, and is not borne out by the facts. It is doubtless not illegal for a manufacturer to indicate an equivalence, since such an expression is not strictly speaking a guaranty, but simply a part of that surplusage with which manufacturers are apt to bedeck fertilizer sacks. Seven of the fourteen companies selling in Vermont do not try thus to mislead their customers; seven, however, for some or all their goods make this doubtful statement. The American Agricultural Chemical Company, the Bowker Fertilizer Company, the Listers Agricultural Chemical Works, and the New England

Fertilizer Company make this inferential claim by the use of the phraseology, "equivalent to sulphate of potash" for their entire output as licensed for sale in Vermont. The Essex Fertilizer Company, the Lowell (Swift's) Fertilizer Company, and the Sanderson Fertilizer and Chemical Company make such claims for two out of six, seven out of ten, and three out of five of their brands respectively. The other companies, the Armour Fertilizer Works, J. F. Bromley, the Buffalo Fertilizer Company, the Burlington Rendering Company, the Coe-Mortimer Co., the Parmenter and Polsey Fertilizer Company, and the Rogers and Hubbard Company make no claims, direct or indirect, inferential or otherwise, as to the source of potash in their goods. Oddly enough claim is made that sulphate of potash is contained in only one of the six brands in which as a matter of fact it is used. In other words the companies which habitually use sulphate of potash make no claim as to its presence, and those which do not use it inferentially claim it to be present. It is of course conceivable, though highly improbable, that some of these goods contain a sufficient amount of chlorin to neutralize the good effects of the sulphate, if any such there be. Only five brands out of the entire 157 contained any material quantity of sulphate of potash. Wherever the asterisk (*) or the dagger (†) appears in connection with the potash figures in the columns thus headed on pages 361 to 375, sulphate of potash was found to be present. Where these signs do not appear, the potash was derived from muriate or from kainit, the "near-fib" of the manufacturer to the contrary notwithstanding.

IV. THE RELATION BETWEEN SELLING PRICE AND VALUATION

The relationship of the selling price to the valuation of fertilizers of different grades has been elaborated annually for nearly 15 years. It has been customary of late to approach the matter from two directions, to make two classifications, basing one on *cost* and the other on *value*. Three groups, somewhat arbitrarily

formed, designated "low priced," "medium priced" and "high priced," furnish the means of comparing the cost, while as many groups termed "low grade," "medium grade" and "high grade" serve the purpose in the study of relative values.

When grouped according to selling prices the item of *cost* is emphasized; when the valuations govern the sub-divisions, the stress is laid upon the *worth* of the material. The selling price may or may not bear an essentially just relation to the plant food content of the fertilizer. The valuation, however, is a more exact measure. Since both cost and worth are important factors, and since some may grasp the facts more readily when presented from one viewpoint while others see the situation better when looked at from the other side, it has been deemed best to present the results of both methods of comparison. The general outcome is much the same either way the proposition is figured.

I. FROM THE STANDPOINT OF COST

The brands may be classified as to selling price as follows:

	Number of brands	Percent of total	Average selling price
Low priced, selling at \$28 or below.....	52	33	\$26.23
Medium priced, selling from \$28.50 to \$32.50	59	38	29.88
High priced, selling for \$33 or more.....	45*	29	38.92

The average, largest and smallest values of plant food offered in the groups of brands appear below. The figures show the values of plant food bought for a dollar in the average goods of each grade, including the greatest as well as the least value obtained in any brand in each class.

VALUE OF PLANT FOOD BOUGHT FOR A DOLLAR

	Average	Smallest	Largest
Low priced	\$0.56	\$0.44	\$0.72
Medium priced	0.62	0.40†	0.76
High priced	0.65	0.55	0.75

*A highly nitrogenous and relatively costly oats and topdressing is omitted from the comparison.

†An absurdly high price locally charged for the lowest grade of goods licensed, a price almost equal to the average.

It is interesting to note the number of brands in each group which furnish less than 55 cents' worth of plant food¹ for a dollar, as well as the number which afforded more than 65 cents' worth for the same sum:

Low priced:	Less than 55c. worth, 27; more than 65c. worth, 6
Medium priced:	Less than 55c. worth, 7; more than 65c. worth, 19
High priced:	Less than 55c. worth, 0; more than 65c. worth, 27

The comparisons can be shown graphically. The relative length of the following lines show the average money value in plant food at retail seaboard prices bought for a dollar at Vermont delivery points in brands selling for \$28 or less, (low priced), from \$28.50 to \$32.50 (medium priced), and for \$33 and above (high priced):

Low priced: 56 cents for a dollar spent.

Medium priced: 62 cents for a dollar spent.

High priced: 65 cents for a dollar spent.

The following lines show the proportion of the total number of brands in each group containing 55 cents or less worth of plant food for each dollar invested:

Low priced: 52%.

Medium priced: 12%.

High priced: 0%.

The final set of lines show the proportion of the total number of brands in each group containing 65 cents or more worth of plant food for each dollar invested of the purchase price:

Low priced: 12%.

Medium priced: 32%

High priced: 60%.

If lines and figures are put into words, it will be seen that:

1. The same amounts of plant food which cost a dollar in

¹The phrase "55 cents' worth of plant food" should be construed to mean an amount of plant food which, if bought for cash at retail at the seaboard, would have cost 55 cents in standard, unmixed, raw materials.

the average low priced brands (\$28 and below) might have been bought in the unmixed state at retail and at the seaboard for 56 cents; in the average medium priced goods (\$28.50 to \$32.50) for 62 cents; and in the average high priced goods (\$33 and upwards) for 65 cents. Extremes of values were 75 and 40 cents. In more than one-fifth of the brands the sums charged for manufacture, transportation, sale, etc., comprised more than 45 percent of the retail cost, thus leaving less than 55 percent to pay for the plant food; while in twelve brands these charges equalled or exceeded the seaboard value of the unmixed plant food.

2. In half of the total number of low priced brands the charges for mixing, sale, etc., aggregated at least 46 percent of the selling price, while in only one in eight of the number of medium priced brands and in not a single one of the forty-five high cost goods were the charges thus large.

3. Three-fifths of the total number of high class goods contained an equivalent of 66 cents' or more worth of plant food at retail seaboard prices. But one in three of the medium grade and but one in eight low grade goods contained so high an equivalent.

These things are naturally so, inevitably so. There are good and sufficient reasons for this showing, which may be condensed in a nutshell as follows: It costs as much to mix, to store, to regrind, to bag, to ship, to freight, to sell, to collect for sales, etc., a ton carrying 1,200 pounds of genuine fertilizer and 800 pounds of mere filler (diluent) as it does to mix, store, regrind, bag, freight, sell, etc., etc., a ton of goods that contains a full 2,000 pounds of undiluted fertilizer ingredients. Hence it follows that the buyer of low grade goods must pay for all this useless handling of the nearly or quite worthless filler. It is an old story, reiterated year after year, but it is one which needs to be told as long as material usage of low grade brands obtains.

2. FROM THE STANDPOINT OF VALUE

Let us now turn the matter about and study it from the standpoint of *worth*. The figures and proportions naturally differ from those just presented. The brands may be classified as to valuation as follows:

	Number of brands	Percent of total	Average valuation
Low grade, valuing at \$15.50 or less.....	41	26	\$13.69
Medium grade, valuing at \$15.51 to \$22.....	72	46	18.47
High grade, valuing at \$22.01 and upwards.	43	28	27.43

The composition, selling price and valuation¹ of the average brand of each group appears in the following table:

	Nitrogen	Available phosphoric acid	Potash	Total plant food, pounds	Average selling price	Average valuation	Selling price exceeds valuation by
Low grade,	0.95	8.60	2.30	11.9	\$26.43	\$13.69	\$12.74
Medium grade,	1.94	8.44	3.90	14.3	29.50	18.47	11.03
High grade,	3.16	7.77	9.06	20.0	38.87	27.43	11.44

A survey of this table indicates that:

1. The proportion of nitrogen increases in regular graduations from group to group; that of phosphoric acid drops three-fourths percent from the lower and medium to the high grade goods; while the potash increases one and one-half percent in the medium and six and three-fourths percent in the high grade brands, as compared with the lower ones.

2. The low grade goods carry nine times as much phosphoric acid as they do nitrogen and nearly four times as much phosphoric acid as they do of potash. These ratios become,

¹Exclusive of one brand, a highly nitrogenous and relatively costly oats and topdressing, the valuation of which is relatively very high.

roughly, four and two in the medium grade. In the high grade fertilizers there are but two and one-half times as much phosphoric acid as nitrogen, and one and one-fourth percent more potash than phosphoric acid. The latter grade more closely resembles the proportions commonly present in the crops ordinarily grown than do either of the other grades.

3. The medium grade goods for one-half advance in price over the cost of the low grade brands offers one-fifth more plant food and one-third more commercial value.

4. The high grade fertilizers for less than one-half advance in price over the cost of the low class goods furnish nearly two-thirds more plant food and more than double the commercial value.

5. The higher the grade the less the margin between cost and worth, both actually and relatively. In buying the average low grade brand, one paid this year \$12.74 for service of one sort or another (factory and office charges, freight, selling expenses, etc.) incurred in the delivery of \$13.69 worth of plant food; when medium grade goods were bought, \$11.03 service charges placed \$18.47 worth of plant food in the buyer's hands; and when high grade goods are bought \$11.44 service charges placed \$27.43 worth of plant food in the buyer's hands. Or, phrasing the matter another way,

THE COST OF PLACING A DOLLAR'S WORTH OF PLANT FOOD IN THE
FARMER'S HANDS WAS:

In low grade goods	93 cents
In medium grade goods	60 cents
In high grade goods	42 cents

It may be worth while now to scan the prices paid for a pound of nitrogen, of available phosphoric acid and of potash in the several grades. The next table shows this, including the average, lowest and highest costs as well as the retail cash cost of these ingredients in Boston or New York, or, in other words, their "valuations." (See pages 308-310, 340-352 this bulletin).

COST OF A POUND OF PLANT FOOD IN FERTILIZERS OF VARIOUS GRADES

	ORGANIC NITROGEN			AVAILABLE PHOS- PHORIC ACID			POTASH		
	Average	Highest	Lowest	Average	Highest	Lowest	Average	Highest	Lowest
	cts.	cts.	cts.	cts.	cts.	cts.	cts.	cts.	cts.
Low grade,	38.6	45.4	27.8	8.4	9.8	6.0	8.2	9.7	5.9
Medium grade,	32.0	48.8	26.4	6.9	10.6	5.7	6.8	10.4	5.6
High grade,	28.3	36.4	26.6	6.1	7.9	5.8	6.0	7.7	5.7
Retail cost, Boston or New York,	20			4½			4¼		

The same lesson enforced in a different way, that cheap fertilizers are the most costly. Some Vermont buyers paid almost a half a dollar for a pound of nitrogen which they might have bought for 26½ cents laid down at their doors in mixed fertilizers. They paid under similar circumstances 10½ cents a pound instead of 5¾ cents for phosphoric acid and 10½ cents for potash instead of 5½ cents. They paid almost double prices because they did not give the matter attention, or, perhaps, because they did not believe in "book farming." The thoughtful buyer of high class goods, sold at not overhigh prices, bought plant food at figures not much in advance of valuations plus freight rates.

It ought to be said in this connection that the same brands similarly named, in different localities, as well as the same goods variously named in one locality or, indeed, in one dealer's hands, are sometimes found to sell at different prices, and, apparently, without good reason. A few exorbitant charges have been noted, as for example, the case noted in the footnote on page 330. Moreover, purchasers often fail to exercise good judgment in their choices and pay overhigh charges owing to lack of information as to what to buy and how to buy it. That this situation is largely their own fault can justly be claimed, since the State has thrown about this trade safeguards which are

lacking with almost every other class of traffic. The yearly fertilizer inspection, the publication of the results of the work, the free distribution of the bulletins, the clear and concise statements as to the brands on sale, the simplicity and directness of the few fundamental facts which are the main guides as to choice and to purchase; all these are ample justification of the statement that, speaking in general terms, he who is dissatisfied with the results attained with fertilizers, so be it weather conditions favor and the seed is good, has himself to thank for it. This dissatisfaction may be due to unwise choice, that is to say the purchase of a goods ill-adapted to a specific purpose; or, it may arise from the realization that one has paid an unreasonably high price in view of the grade of the goods. In either case a repetition of the experience may be avoided by the exercise of a little care as to choice. Particularly in the matter of purchase there often appears to be but little relation between price and plant food content. Thus, for example, goods guaranteed to carry uniform available phosphoric acid contents, but the highly variable nitrogen and potash contents noted below have been found in recent years selling at a uniform price at points where freight rates were not materially unlike:

Nitrogen, 33 lbs.;	potash, 40 lbs.;	nitrogen and potash, 73 lbs.
Nitrogen, 41 lbs.;	potash, 30 lbs.;	nitrogen and potash, 71 lbs.
Nitrogen, 16 lbs.;	potash, 80 lbs.;	nitrogen and potash, 96 lbs.
Nitrogen, 41 lbs.;	potash, 60 lbs.;	nitrogen and potash, 101 lbs.

Frequently two brands of the same make with identical nitrogen and phosphoric acid guaranties but with different potash guaranties (1.5 and 3 percents) are found sold at a flat price. That is to say a local agent will offer a corn fertilizer at \$30 and a potato phosphate at \$30, each containing equal amounts of nitrogen and phosphoric acid, but the latter twice as much potash as the former. This is no sin; neither is it against the law. But what well-informed buyer would choose the corn goods in preference to the potato brand? Yet doubtless many do.

Identical but differently named goods were sometimes sold by one and the same agent at different prices. Again, two brands with similar nitrogen and phosphoric acid guaranties but different potash figures were sold by the same agent at different prices, the higher price being asked for the lower guaranteed goods.

A few more examples of some of these anomalies may serve to cause some buyers the more carefully to scrutinize their purchases.

A Washington County agent offered at identical prices goods made by the same company guaranteed as follows:

Nitrogen	Total phosphoric acid	Available phosphoric acid	Potash
2.47	9	8	4
1.65	9	8	2

The first carried a quarter part more available plant food than the second; but they were offered at the same price. This same dealer only charged three dollars a ton more for goods made by the same manufacturer containing 2.5 percent nitrogen and 10 percent potash. For an advance of 10 percent in price, he furnished almost 60 percent more plant food.

Another agent in the same county offered two low grade goods of the same make, one carrying a percent each more available phosphoric acid and potash and a quarter of a percent more nitrogen, or one-fourth more total plant food than did the other; but both sold at the same price and both were costly purchases, for one furnished but 47 cents' worth and the other 44 cents' worth of plant food for a dollar.

An Addison County dealer offered corn and potato goods of the same make, the one guaranteed to carry a third more nitrogen than the other and an equal amount of the other ingredients at a uniform price. Other and similar cases might be cited.

The non-nitrogenous brands, twelve of which are licensed, being relatively cheap are quite popular and somewhat widely sold. As a class they carry costly plant food. As sold this year in Vermont they average to offer only 54 cents' worth of

plant food for a dollar. When one has ample home supplies of nitrogen, non-nitrogenous goods may prove advisable purchases; but commercially they are usually expensive plant food.

3. AS BETWEEN MANUFACTURERS

One company averaged to charge 43 cents for placing a dollar's worth of plant food in the buyer's hands. Yet another asked 81 cents for the same service. In the one case a dollar bought 70 cents' worth of plant food, in the other 55 cents' worth. For half of the brands offered by each of three companies was asked from 80 cents upwards for the laying down of a dollar's worth of plant food at the buyer's depot; or, stating it another way, the buyer of their low priced brands paid from \$1.79. to \$2.24 and received therefor a dollar's worth of plant food. His neighbors paid in some cases as low as \$1.33 for a dollar's worth. Which made the wiser purchase? It is not difficult for anyone to apply this test before purchase. Thus, for example: Selling price, \$30; guaranty, nitrogen 2%; soluble, reverted and insoluble phosphoric acids, 6, 3 and 1%¹; potash, 3%; $2 \times 20 \times .20 = 8.00$.¹ $6 \times 20 \times .045 = 5.40$. $3 \times 20 \times .04 = 2.40$. $1 \times 20 \times .02 = 0.40$. $3 \times 20 \times .0425 = 2.55$. $\$8.00 + \$5.40 + \$2.40 + \$0.40 + \$2.25 = \18.75 . $18.75 \div 30 = 63^2$; or $30 \div 18.75 = 1.67^3$. Sixty-seven cents' service charge for a dollar's worth of plant food. Sixty-three cents' worth of plant food for a dollar spent.

V. CONCERNING THE BUYING OF COMMERCIAL FERTILIZERS

The commercial fertilizer trade of Vermont is rapidly increasing and now approximates \$600,000 annually. The purchases doubtless are made for the most part without much reference to the quality of the goods. Choice is dictated sometimes by past experience, by a neighbor's or an agent's statement, by

¹ I. e., 2% (or 2 pounds per 100) nitrogen, multiplied by the trade value of a pound of nitrogen (20 cents) affords the valuations of the guaranty of nitrogen, \$8.00. The other calculations are similarly made.

² Valuation divided by cost equals worth of plant food per dollar spent.

³ Cost divided by valuation indicates service charge paid for a dollar's worth of plant food bought.

an apparently low price or, perhaps, by an attractive name. The average buyer, if he gives any thought to, or knows anything whatsoever about, the Station's relation to the trade doubtless reasons much as follows: "The Experiment station analyzes the fertilizers and they are all right." Such reasoning, however, is faulty. Neither the fact that the law is on the statute books, nor that the Station executes it, makes all commercial fertilizers good, or the purchase of a given brand a wise procedure. Legal enactments, a manufacturer's reputation for fair dealing, glowing testimonials and the like have value; but neither they nor any other guide can take the place of the intelligent discrimination of the individual farmer, a discrimination born of experience and judgment. The Experiment station cannot give the buyer experience; but it may help him in the matter of judgment. If he learns the different forms of plant food, if he understands the interpretation of analyses, guaranties, commercial values and the like, if he has studied his crops and soils and got some inkling of their needs, if in short he has studied the bulletins or listened to the "Farmers' Week" addresses on fertilizer buying, he is on that account the more apt to be in a position to make a better choice, to get a larger commercial value and, probably, a larger agricultural value for a given sum than is he who buys more at random.

The Station in its inspection work is concerned simply with comparing the promises with the performances of the seller and with indicating the cash costs of equivalent amounts of plant food. The buyer, however, who wishes to make a rational choice and an economical purchase, while giving due weight to these points, needs also consider other matters involving careful farm management and wise business methods. He should ask himself the following questions:

To what use am I to put purchased plant food? Do my soils and crops need nitrogen, phosphoric acid or potash, any two, or all three of these? Do they need lime? Shall I use these materials to supplement barnyard manure, as a "starter"

to hoed crops, or alone? What proportions of the sundry ingredients will best fit my needs? How can I get what I need at the least cost? Shall I buy chemicals and home-mix? Or shall I club with my neighbors and buy on special order? Or, if I must buy a "ready made" goods, can I not find on sale in my neighborhood several brands made by reputable firms which, judging by guaranties and by station analyses in years gone by, bid fair to meet my needs? May I not readily ascertain which of these offers the most plant food for a given price?

The farmer who thus reasons out the wisdom of his purchase is more likely, as has already been remarked, to get good values than is he who makes a haphazard choice.

Some of the points which bear upon selection and purchase may be stated—not of necessity in the order of their relative importance—as follows:

1. The results personally obtained by reliable, careful, observing farmers on similar soils and crops.
2. The character, previous cropping and manuring of the soil.
3. The demands of the future crop for plant food.
4. The quality and amount of barn-yard manure available for use.
5. The fitness of the several goods as judged by guaranties and analyses for soil, crop and as a supplement to home manurial supplies.
6. The form in which the ingredients occur (nitrogen as nitrates, a high grade of organic matter, etc., potash as muriate, sulphate, etc.).
7. The reputation of firms offering goods.

1. AS TO GUARANTIES

The state law requires manufacturers of commercial fertilizers to print on each package the amounts and kinds of plant food it contains. It further requires that this statement shall be a true one. It neither prescribes how much shall be promised,

nor what price shall be asked for the goods. There may be only a small amount of plant food furnished, or the brand may be a highly concentrated one. Its cost may be high or low, bearing some relation to the actual value of the goods or none whatever. The law does not interfere here; and hence it is, as has been hitherto pointed out, that the buyer's best protection lies not in the law but in his own special information. The old-time legal maxim "*Caveat emptor*"—let the buyer beware—holds in the purchase of fertilizers as in that of other commodities, notwithstanding the safeguards of the law, which simply provides, as above remarked, that the manufacturer shall state what amounts and kinds of plant food he offers and that he shall keep his promise. This promise constitutes the manufacturer's "guaranty." If, therefore, in the table of analyses under the headings "Total Nitrogen guaranteed," "Total Phosphoric acid guaranteed," "Available Phosphoric acid guaranteed," and "Potash guaranteed" are found for a given brand respectively the figures 1.64, 8, 7, and 4 (guaranties are always printed in the tables in *italics* and are the only figures thus printed) it means that the manufacturer of the brand in question promises to furnish 1.64 percent of total nitrogen, 8 percent of total and 7 percent of available phosphoric acid, and 4 percent of potash, equivalent, of course, to 32.8 pounds of nitrogen, 160 and 140 pounds of total and available phosphoric acids (the 140 pounds available being included within the 160 pounds) and 80 pounds of potash to the ton. The black face figures in the tables in the columns immediately preceding the guaranty columns indicate the actual amounts of the sundry forms of plant food found to be present by analysis. They show how well the promises are kept.

The guaranties, as they are printed on the bags or the attached tags, or in the little booklets often used as advertisements, are apt to be so made that, while meeting legal requirements, they confuse the buyer and convey wrong impressions. The branding of the bags may be illegible, the terms used ill-defined, and the figures

irrational. Nitrogen, phosphoric acid and potash are often expressed as ammonia, bone phosphate of lime, and sulphate of potash, in order to make an appearance of giving large percentages of plant food; and, it would seem sometimes, to make a vast and confusing array of figures. There is and can be nothing in the law forbidding the manufacturer printing anything he wishes on the bags. He can stencil quotations from Shakespeare or Mr. Dooley thereon if he wishes to do so and no law can thus restrain him against his will.

The following statement shows a guaranty made in recent years upon a certain brand sold in Vermont. On its right is shown this guaranty statement reduced to its "simplest terms."

Nitrogen	0.82— 1.64	
Nitrogen as ammonia..	1.00— 2.00	
Soluble phosphoric acid	6.00— 7.00	
Reverted phosphoric acid,		
	2.00— 3.00	
Insoluble phosphoric acid,		
	1.00— 2.00	Nitrogen
Total phosphoric acid,	10.00—12.00	Available phosphoric
Bone phosphate of lime,		acid.....
	22.00—25.00	Potash.....
Available bone phosphate		
of lime	18.00—20.00	
Available phosphoric acid,		
	8.00—10.00	
Potash	4.00— 5.00	
Equivalent to sulphate		
of potash	8.00—10.00	

Eleven statements as against three; thirty-four words and seventy-four figures instead of five words and five figures. Each guaranty indicates the same grade of goods. The shorter one is sufficient, though it does not meet the letter of the law as regards certain minor matters. The longer one shows many things the law does not ask for and makes one statement which is almost a misstatement. It is meant, in some measure at least, to mislead the buyer, to make a semblance of offering more than is actually contained. And the scheme no doubt often succeeds. Probably if the selfsame goods were sacked in two lots, bearing the two guaranties given above, the larger part of the buyers

—if they looked at the guaranty at all—would choose the goods branded with the longer stencil. “Nitrogen equivalent to ammonia (or ‘as ammonia’), 1.00 percent” guarantees but 0.82 percent nitrogen, “bone phosphate of lime, 22 percent,” but a little over 10 percent phosphoric acid, and “sulphate of potash, 8 percent,” but a trifle over 4 percent potash. These extra figures in guaranties are meaningless and superfluous.

It should be noted, moreover, that the higher or maximum guaranties are entirely without validity and that they are used for the same purpose, to make an appearance of giving more plant food than is actually present. Potash 4 to 5 percent, for instance, guarantees but 4 percent of that ingredient, the 5 percent being a superfluity. Buyers should remember this and ignore in the guaranty everything but the lower figures for nitrogen (not ammonia or nitrogen equivalent to ammonia), available phosphoric acid (not bone phosphate of lime), and potash (not sulphate of potash or potash equivalent to or equal to sulphate). In cases where ammonia (or nitrogen equivalent to ammonia), or sulphate of potash, or bone phosphate of lime only are known, their nitrogen, potash and phosphoric acid equivalents may be obtained by multiplying their respective guaranties by 0.82, by 0.54 and by 0.46.

It is clear that the buyer of commercial fertilizers who consults the guaranty as a guide to purchase, needs to be on his guard as to its interpretation. It is suggested that the analyses of the station bulletin tables be consulted in this matter. Every effort is made to secure accuracy in the correct rendition of these—to the layman—confusing figures. It should be remarked, however, that, since there are occasional changes in the guaranties, an old guaranty may not be correct for this year's goods of the same name. In other words, the name of the brand may remain unchanged but its guaranteed composition, its crop-producing power, may be altered; for a manufacturer may change his guaranty as often as he wants to, daily in fact, if he wishes

to do so, so long as he purveys every time as much as he promises.

2. AS TO BRAND NAMES

Brand names may or may not bear relation to the usefulness of the goods. Far too often the words "bone," "guano," "dissolved bone," "high grade," etc., have no significance; frequently the more high flown the name, the lower the grade of the goods; and it often happens that so-called special fertilizers but poorly suit the nature of the crops whose names they bear. Indeed the variations in formulas and guaranties of goods intended for the same crop show that the manufacturers are not a unit in their views as to the crop requirements.

The very firms which strenuously assert the importance of special fertilizers shovel several from the same bin, selling the selfsame goods as corn fertilizers, as potato manures, and as good for all kinds of crops. In fact, as one manufacturer remarks, buyers "prefer to see the word 'potato' on the bags when the goods are purchased for that crop, and 'corn' when bought for the corn crop." And the local agent is quite apt to charge the buyer a couple of dollars more a ton for the pleasure he derives from seeing the word "potato" instead of the word "corn" on the bags. Instances of this sort are found in each year's inspection. Another case may be cited where a long time standard goods was sold at a much higher price than was the selfsame fertilizer when it bore another and less well known name, both brands being offered by the same local agent. A difference in the selling price of these two differently named but identical goods has been observed in previous years. A few minutes study of the meaning or guaranties,—pages 361-376,—and a moment's scanning of those printed on the bags, or of the analyses in the station bulletin, would show in either of the cases cited that the two goods are the same thing sold under different names, and a needless outlay would have been saved. This condition of affairs affords one of the many valid reasons for the law which requires a guaranty of composition and conformity therewith.

Indeed this matter of the multiplication of brands forms one of the anomalies of the fertilizer business as now conducted. There were 161 so-called brands licensed in Vermont in 1911. As a matter of fact there were really only half that number of different kinds of fertilizers sold—84 to be exact—owing to the sale of the same goods under different names. One company sold goods under 63 different names. It really offered, however, but 18 different grades. It sold 6 grades under 48 different names, and 3 grades under 34 names. These variously named goods in each grade were all alike, all apparently made according to the same formula and presumably all, or nearly all, shipped from the same pile. The same thing is true to a less extent of other companies selling in Vermont.

There is nothing illegal about the practice; but it does no good to the farmer. On the contrary it tends to increase the cost of fertilizers. If consumers bought more often on a basis of the plant food content, rather than by name and apparent cheapness, this condition would be less likely to be met. Nitrogen, phosphoric acid, potash, lime, sulphate of lime, humus and the like are what force plant growth rather than the name stenciled on a fertilizer bag.

3. AS TO VALUATIONS

Year after year the meaning of the valuation system is unfolded in the station bulletins, both in connection with the schedule and as a footnote to every table of analyses. Black faced type and italics are used to emphasize this matter and to point out more particularly what these valuations are not. Yet notwithstanding this extreme care they doubtless are often misunderstood and misused. Indeed this condition is met to such an extent that the application of money valuations to fertilizers is omitted by several fertilizer controls. The writer, however, believes that they serve a good purpose when properly used, and that it is better for the present at least to employ them than to abandon them, laying, however, all possible stress on their true meaning,

repeating, reiterating, stating and then restating in another form, the more surely to accomplish the desired end.

The "valuations" simply show the *retail cash value of raw unmixed plant food of good quality in Boston and New York*. Thus for example we will assume that the system is applied in due course to an analysis of Smith's Sugarcane Grower and that the nitrogen in a ton "valued" at \$7.94, the phosphoric acid "valued" at \$8.68 and the potash "valued" at \$6.81. These statements, which are just such as are made in the tables of analyses pages 361-375 under the headings of "Valuation of nitrogen in one ton" (and similarly for the other two ingredients), *do not mean* that a ton of Smith's Sugarcane Grower is worth \$7.94+\$8.68+\$6.81 or \$23.43. They *do not mean* that \$23.43 is a proper price to pay the local agent for this brand. They *do not mean* that this is the price at which the agent bought. They *do not mean* that this is the service a ton of this brand is likely to give the farmer expressed in terms of money. They *do not mean* that this sum is the commercial value of the brand; much less do they mean that it is any measure of its agricultural worth. What they *do mean* and *all they mean* is simply this: that *the same amounts of the very best forms of plant food as are found in a ton of Smith's Sugarcane Grower could have been bought at retail in an unmixed condition in Boston or New York during the past fall and winter for \$23.43*. They *do not mean* that the plant food the manufacturer used of necessity had this commercial value during this time. It may have had a less one, but it can hardly have had a greater (except in cases of marked fluctuations during the fall and winter in the prices of the crude fertilizing materials, or unless the manufacturer deliberately elected to use commercially expensive forms of nitrogen and phosphoric acid). The Station does not pretend dogmatically to state the commercial worth or valuation of any given fertilizer. And as for its agricultural value, its crop producing power, no man can say. Adverse weather conditions, insect depredations, blight injuries,

poor tillage, the use of insufficient amounts, or a dozen other contingencies may make the best of plant food of little service.

It will be seen by this that valuations simply show the cost of ready-made plant food. The cost of this plant food, however, is but one of the many charges which determine the retail cost of commercial fertilizers as sold in Vermont. It is the main item, but there are others. The sundry forms of plant food when ready for use in making commercial fertilizers have to be mixed, stored, reground, bagged, loaded, and freighted. Then, too, commissions to agents and dealers, the expense of selling on long credit, the item of bad debts, the interest on investments, the depreciation of the manufacturing plant, profits, etc., are also proper and fixed charges. All these cost money and must, in the end, be paid for by the consumer of mixed fertilizers. Not one of them contributes in the least to plant growth. Commercial fertilizers are usually applied in the mixed form, but this is simply a matter of convenience. The mixing adds no virtue to them (except the mixing of sulphuric acid with raw phosphate) and as good results may be obtained by the separate application of the crude ingredients. (See pages 308-310 for a further exposition of this matter).

There are arguments both for and against the use of valuations. The opponents of the system say:

1. The prices of raw materials vary from time to time. Logically valuations should shift similarly.

2. They are misleading, misunderstood, misapplied and, therefore, mischievous.

3. Chemical analysis does not disclose the sources of the various forms of plant food in the mixtures and hence it is difficult, if not impracticable, to apply true commercial values.

4. The use of certain forms of plant food is encouraged while that of other forms is discouraged.

Its advocates say in its defense:

1. Prices of raw materials do vary; but that fact has but little bearing in this matter. Comparative and not absolute

values are shown by the valuation system. It is emphatically and distinctly disclaimed that any attempt is made to show the commercial valuation of a given brand.

2. The uninformed or the careless may be misled; but the system is so simple and its meaning made so clear that it ought not to be misunderstood by anyone of fair intelligence. It may be misapplied by those who are misled or who misunderstand it. Many good things may be perverted through misuse; but this is not a valid argument against them. The farmer who thinks that money values are an index of crop producing merit has no conception of the meaning or use of the system. The kinds and amounts of plant food rather than its money value determine the agricultural worth of a fertilizer.

3. A full chemical analysis of a commercial fertilizer, such as the Station has printed in its bulletins for years, gives every clue needed as to source and kinds of phosphatic and potassic plant food. It shows too the proportions of mineral and organic nitrogens and this year for the first time attempts to discriminate as to the serviceability of the organic nitrogen. Hitherto the chemist's analyses have shown how much organic nitrogen is present, but did not indicate how good it was. But now the tale is told as fully for nitrogen as for phosphoric acid and for potash. (See pages 319-327). It should be noted that here the objectors to the valuation system miss the point. The nitrogen valuations show the retail cash cost of equivalent amounts of high grade forms of nitrogen, the two mineral and organic forms as such. They *do not* show the retail cost of the nitrogen used in the brand in question, all of which may or may not have been of good quality.

4. The valuation system does seem to favor the use of rock phosphates rather than of bone phosphates. Commercial conditions, however, have for years been such that the former has been the cheaper. A pound of soluble phosphoric acid from one is, so far as is known, of equal agricultural value to a pound of the other. The reverted phosphoric acid from each source is probably of nearly equivalent agricultural values, with that

derived from bone or bone black perhaps a bit the better. The insoluble phosphoric acid derived from bone is agriculturally better and commercially more costly than is its competitor. The trade values for soluble and available phosphoric acids are based more on rock than on bone prices, while that for insoluble phosphoric acid is a sort of compromise. Since the available (soluble and reverted) phosphoric acid in the rock goods is almost if not quite as serviceable agriculturally as that from bone, and since it is much cheaper, it is generally to be preferred. This condition is reflected in the trade values for this ingredient.

Those who have fathered the system say for it that, while it is open to misuse, it is particularly serviceable in two ways:

1. To show whether a given fertilizer is worth its cost from the *commercial* standpoint.

2. As a common basis on which to compare the *commercial* values of different brands, enabling buyers to note whether prices asked are warranted by values contained.

It expresses these highly variable percentages in concrete shape. Many farmers are not as well acquainted with nitrogen, phosphoric acid and potash as they should be; but they know dollars and cents. And if they realize that these values expressed in terms of dollars and cents are a purely commercial measure and not an agricultural one, the system should be of service to them.

It has been suggested that it were better to express the valuations in the tables pages 361-375 of analyses all as one figure instead of splitting them between the three ingredients. This is the common procedure in other states but it has not approved itself to the writer. By dividing the figures thus it emphasizes the fact that these values spring from the sundry forms of plant food. It calls attention to nitrogen, phosphoric acid and potash instead of leading one away from their consideration. It prepares the way for a better understanding of the whole matter and, indeed, it is to be hoped, for the ultimate abandonment of the valuation system.

How are valuations calculated? Trade values having been established in the manner referred to on page 308, the percentages or pounds per hundred of each ingredient, (i. e. nitrate nitrogen, ammoniacal nitrogen, total organic nitrogen, soluble phosphoric acid, reverted phosphoric acid, insoluble phosphoric acid and potash), are first multiplied by 20. This gives the number of pounds of each ingredient in a ton. These figures are then multiplied by the respective prices per pound. Thus for example the procedure in the case of the analysis of the Essex Fertilizer Co.'s XXX Fish and Potash, shown near the bottom of the eleventh pages of the tables on pages 361-375, was as follows:

Ingredient	Percent	Pounds in a ton	Price per pound	Valuation
Nitrate nitrogen,	None			
Ammoniacal nitrogen,	0.53	x 20 = 10.6	x 16c =	\$1.70
Organic nitrogen,	1.90	x 20 = 38.0	x 20c =	7.60
Total nitrogen valuation,				\$9.30
Soluble phosphoric acid,	5.96	x 20 = 119.2	x 4½c =	\$5.36
Reverted phosphoric acid,	2.60	x 20 = 52.0	x 4c =	2.08
Insoluble phosphoric acid,	1.12	x 20 = 22.4	x 2c =	0.45
Phosphoric acid valuation,				\$7.89
Potash,	3.36	x 20 = 67.2	x 4¼c =	\$2.86

Had the chemist found the potash to be in the form of sulphate, 5 cents per pound would have been allowed instead of 4¼ cents.

4. AS TO AGRICULTURAL VALUES

The agricultural value of a commercial fertilizer is measured by the increase in the size of the crop. This is obviously a fluctuating figure, varying with different conditions of soil, season, etc., from zero, or sometimes less than zero, to a large sum. Many of the factors which modify field results are quite beyond human foresight or management. Others, however, may in some measure be controlled. Prominent among those pertaining more particularly to the fertilizer is the form of the plant food in its relation to availability. The slower kinds of plant food, those which are relatively insoluble or which resist decay

are much less likely to yield profitable returns with hoed crops than are the quick, active, soluble forms. The market value of the harvest is another item worth considering, for crops of relatively low money values cannot be profitably raised with costly plant food.

It is clear that agricultural and commercial values bear no necessary relationship. Indeed it may happen that, owing to commercial considerations, the cost of a material of relatively low agricultural value may be greater than that of one of higher agricultural worth. Thus for example plaster, lime, stable manures and the like may bear prices which in view of their low contents of direct fertilizing ingredients are relatively high.

5. AS TO FORMS OF PLANT FOOD

It is common in speaking of plant food to use the word "form." For instance it may be said that nitrogen occurs in the "form" of nitrate or that potash is found in the "form" of sulphate. "As," or "in" nitrate and "as" or "in" sulphate are alternative expressions. This term "form" as thus used refers to the union of the element or constituent in question with others, the combination or association in which it is bound. The use of the phrase "potash in the form of sulphate," or "potash as sulphate," for example, is an intimation that this valuable plant food exists in the case under consideration united with sulphuric acid as sulphate of potash, differing thus from the muriate (chlorid), or other forms in which it might have occurred. The word "form" serves to point out, so to speak, the company the plant food keeps. This is an important office. The ingredients with which the sundry kinds of deficient plant food (nitrogen, phosphoric acid, potash and, often, lime) are associated vary widely. There are many of them. Some may be useful, some harmless or inert, some, indeed, at times may be harmful. The form in which the plant food occurs, moreover, is important as an index of its availability and, hence, of its service to plant life. Thus for example phosphoric acid, united with but one part of

lime, is soluble in water and promptly assimilable by plants; and when associated with three parts of lime it is insoluble and available at best with extreme slowness. A fertilizer may carry its nitrogen in the form of crude leather, its phosphoric acid may be derived from undissolved rock, and its potash from green-sand marl. Such a material would be almost useless to crop growth. The "forms" in which the elements are present in the above cited case are undesirable, in that they are unavailable, for the reason that the several solvents of the plants and soils are not strong enough to break down such combinations, as must needs be done before plant food can be used. When, however, the phosphate rock is treated with sulphuric acid and its phosphoric acid is thus made soluble, it becomes available and desirable: for plant roots can disintegrate the new union and use it. When this happens, the phosphoric acid has not been changed in any respect, but its "form" has been altered. "Form" then discloses character. An analysis which showed the gross amounts of the sundry plant foods without disclosing their forms would obviously fail in its mission. The full analysis, however, points out not only *how much* but *what kinds* of nitrogen, phosphoric acid and potash are present; and the discussion of the results of inspection so far as it pertains to this matter of the plant food values, shown on pages 319-329 under the caption "quality of plant food," and on pages 311-319 under the caption "quantity of plant food" serves to accentuate this distinction.

V. OBSERVANCE OF THE FERTILIZER LAW

LIST OF LICENSED COMMERCIAL FERTILIZERS

The following companies have paid licenses on the brands specified on this and the next six pages as well as on the four brands listed on page 359, no samples of which were drawn. The list also shows the points at which samples were drawn and the laboratory sample numbers, referring to the analyses on pages 361-375.

AMERICAN AGRICULTURAL CHEMICAL CO., 2 Rector St., New York, N. Y.

- B 1. Grass and Lawn Topdressing; Brattleboro.*
- K 6. Grass and Oats Fertilizer; Bradford.*
- G 7. High Grade Fertilizer with Ten Percent Potash; Groton.*
- J 2. Northwestern Challenge Crop Grower; Irasburg.*
- K11. XXX Phosphate and Potash; Bennington.*

(Bradley Fertilizer Co. brands.)

- K 9. Alkaline Bone with Potash; Groton.*
- J 16. Complete Manure for Potatoes and Vegetables; Bellows Falls.*
- A 1. Complete Manure with Ten Percent Potash; Burlington.*
- B 8. Corn Phosphate; Ludlow.*
- E10. Eclipse Phosphate for all Crops; Bethel.*
- E12. Green Mountain Special; Newport.*
- A 2. High Grade Potato and Root Special; Burlington.*
- E13. Niagara Phosphate; Groton.*
- B 9. Potato Fertilizer; Ludlow.*
- B10. Potato Manure; Chester.*
- E11. Vermonter for all Crops; Windsor.*
- E 9. XL Superphosphate of Lime; Sutton.*

(Clark's Cove Fertilizer Co. brands.)

- J 9. Bay State Fertilizer G. G.; Brownington.*
- H 8. King Philip Alkaline Guano for all Crops; Highgate.*
- H 4. Potato Fertilizer; Underhill Center.*

(Cleveland Dryer Co. brands.)

H14. *Fertilizer for all Crops*; Enosburg Falls.

D 4. *Potato Phosphate*; Windsor.

D 5. *Superphosphate*; Windsor.

(Crocker Fertilizer and Chemical Co. brands.)

D 2. *Ammoniated Corn Phosphate*; Bradford.

D 1. *New Rival Ammoniated Superphosphate*; Coventry.

C16. *Potato, Hop and Tobacco Phosphate*; Springfield.

D 3. *Special Potato Manure*; Springfield.

(Cumberland Bone Phosphate Co. brands.)

H10. *Guano for all Crops*; Walden.

J 12. *Potato Fertilizer*; Johnson.

D 6. *Superphosphate*; West Burke.

(Darling Fertilizer Co. brands.)

H15. *Farm Favorite*; Newbury.

K13. *General Fertilizer*; Waterford.

(East India Chemical Co. brands.)

E 7. *Complete Potato Manure*; Groton.

D 6. *Harvest Home Phosphate*; North Pownal.

J 7. *Standard UnXID Fertilizer*; Jericho.

(Great Eastern Fertilizer Co. brands.)

H11. *Garden Special*; East Hardwick.

C12. *General Fertilizer*; Newport.

D10. *Northern Corn Special*; Newport.

E 8. *Potato Manure*; Bradford.

(Pacific Guano Co. brands.)

D11. *Nobsque Guano for all Crops*; Newport.

B 6. *Potato Special*; Brattleboro.

B 7. *Soluble Pacific Guano*; Burlington.

(Quinnipiac Co. brands.)

E 6. *Climax Phosphate for all Crops*; Montpelier.

B 3. *Corn Manure*; Brattleboro.

J 8. *Market Garden Manure*; East Poultney.

B 2. *Potato Phosphate*; Brattleboro.

(Read Fertilizer Co. brands.)

- H 7. Farmer's Friend Superphosphate; St. Albans.*
- H 8. High Grade Farmer's Friend Superphosphate; St. Albans.*
- J 11. Leader Blood and Bone; South Northfield.*
- H 6. Potato Manure; Moscow.*
- H 5. Practical Potato Special Fertilizer; Moscow.*
- J 10. Standard Superphosphate; Northfield.*
- K 12. Sure Catch Fertilizer; North Bennington.*

(H. F. Tucker Co. brands.)

- G 9. Imperial Bone Superphosphate for all Crops; Jonesville.*
- E 5. Imperial Bone Superphosphate for Corn; Dorset.*
- E 4. Imperial Bone Superphosphate for Potatoes; Dorset.*

(Williams & Clark Fertilizer Co. brands.)

- J 5. Americus Ammoniated Bone Superphosphate; Essex Junction.*
- B 4. Americus Corn Phosphate; Brattleboro.*
- E 1. Americus High Grade Special for Potatoes, Roots and Vegetables; Brattleboro.*
- B 5. Americus Potato Manure; Brattleboro.*
- J 12. Potato Phosphate; Morrisville.*
- E 3. Prolific Crop Producer; Montpelier.*
- E 2. Royal Bone Phosphate for all Crops; Bennington.*

ARMOUR FERTILIZER WORKS, 930-938 Equitable Building, Baltimore, Md.

- D 8. Complete Manure; Bellows Falls.*
- D 7. Corn Special; Bellows Falls.*
- J 1. General Farm; Pownal.*
- D 9. High Grade Potato; Bellows Falls.*
- K 5. Oats and Clover Special; Bellows Falls.*

BOWKER FERTILIZER CO., 43 Chatham St., Boston, Mass.

- G 8. *Corn Phosphate*; Coventry.
- E16. *Early Potato Manure*; Bethel.
- E15. *Hill and Drill Phosphate*; Lyndonville.
- E14. *Market Garden Fertilizer*; Marshfield.
- B13. *Potash Bone*; Cavendish.
- B12. *Potash or Staple Phosphate*; Cavendish.
- G13. *Potato and Vegetable Fertilizer*; Marshfield.
- G14. *Potato and Vegetable Phosphate*; Lyndonville.
- K11. *Soluble Potash Phosphate*; Pownal.
- G12. *Square Brand Bone and Potash*; Walden.
- A 3. *Stockbridge Special Complete Manure for Corn and all Grain Crops*; West Rupert.
- B14. *Stockbridge Special Complete Manure for Potatoes and Vegetables*; Cavendish.
- G10. *Stockbridge Special Manure for Seeding Down*; Brandon.
- G 9. *Stockbridge Special Complete Manure for Topdressing and for Forcing*; Lyndonville.
- K 1. *Superphosphate with Potash*; Richmond.
- G11. *Sure Crop Phosphate*; Concord.
- B11. *Vermont Grange Chemicals, D. Brand*; Cavendish.

J. F. BROMLEY, Granville, N. Y.

- A12. *Banner Brand*; Fair Haven.
- F 2. *Corn and Potato*; Hartland.
- K 2. *Grass and Grain*; Hartland.
- A11. *Green Mountain Brand*; Fair Haven.
- A 8. *Potato Special*; Ira.
- A10. *Special Corn Fertilizer*; Ira.
- A 7. *Special Potato Fertilizer*; Ira.

BUFFALO FERTILIZER CO., William St. near city line, Buffalo,
N. Y.

- C10. Celery and Potato Special*; Woodstock.
- K 4. Extra Phosphate and Potash*; Bennington.
- C 7. Farmers' Choice*; Felchville.
- K 3. General Crop*; Concord.
- C 8. High Grade Manure*; South Royalton.
- C 9. New England Special*; Woodstock.

BURLINGTON RENDERING CO., North Avenue, Burlington, Vt.

- C 1. Animal Fertilizer*; Coventry.
- F 1. Special Potato Fertilizer*; Manchester.

COE-MORTIMER CO., 51 Chambers St., New York, N. Y.

- H 3. Columbian Corn and Potato Fertilizer*; Stowe.
- H 2. Extra Special Potato Fertilizer and Fruit Grower*;
Danville.
- F11. Gold Brand Excelsior Guano*; Montpelier.
- H 1. High Grade Ammoniated Bone Superphosphate*; Danville.
- F12. New Englander Corn and Potato Fertilizer*; South Shaftsbury.
- K10. Prize Brand Grain and Grass*; Danville.
- C13. Special Potato and Fruit Grower*; Pownal Center.
- F10. Standard Potato Fertilizer*; South Shaftsbury.

ESSEX FERTILIZER CO., 39 North Market St., Boston, Mass.

- H12. A1 Superphosphate*; Hardwick.
- F15. Complete Manure for Corn, Grain and Grass*; Vergennes.
- F14. Complete Manure for Potatoes, Roots and Vegetables*;
Bradford.
- C11. Grain and Grass Fertilizer*; Newport.
- F16. Market Garden and Potato Manure*; Montpelier.
- F13. XXX Fish and Potash*; Barton.

LISTER'S AGRICULTURAL CHEMICAL WORKS, Newark, N. J.

- D14. G. Brand*; Ludlow.
- K 8. Grass and Grain Fertilizer*; Middlebury.
- D12. Oneida Special*; South Londonderry.
- G 1. Potato Manure*; Plainfield.
- A14. Special Corn Fertilizer*; Middlebury.
- A15. Special Potato Fertilizer*; Middlebury.
- D13. Special Ten Percent Potato Fertilizer*; Randolph.
- A13. Success Fertilizer*; Middlebury.

LOWELL (SWIFT'S) FERTILIZER CO., 44 North Market St., Boston,
Mass.

- A 4. Animal Brand for all Crops*; West Rutland.
- A 6. Bone Fertilizer for Corn, Grain, Grass and Vegetables*;
Rupert.
- F 4. Cereal Fertilizer*; Bennington.
- A 7. Empress Brand*; West Rupert.
- F 3. Potato Manure*; South Royalton.
- D15. Potato Phosphate*; South Royalton.
- F 6. Special Corn and Vegetable Manure*; Vergennes.
- F 5. Special Potato Fertilizer*; Groton.
- A 5. Sterling Phosphate*; West Rupert.
- H13. Superior Fertilizer with Ten Percent Potash*; Essex
Junction.

NEW ENGLAND FERTILIZER CO., 42 North Market St., Boston,
Mass.

- J 15. Complete Manure*; Saxtons River.
- G 2. Corn and Grain Fertilizer*; Orleans.
- C14. Corn Phosphate*; Coventry.
- C15. Peerless Fertilizer*; Coventry.
- G 3. Potato Fertilizer*; Coventry.
- J 14. Superphosphate*; Whiting.

PARMENTER AND POLSEY FERTILIZER CO., 40 North Market St.,
Boston, Mass.

- G 15. *Corn and Grain Fertilizer*; East Hardwick.
- J 3. *Grain Grower*; Springfield.
- F 8. *Plymouth Rock Fertilizer*; Concord.
- F 7. *Potato Fertilizer*; Bristol.
- F 9. *Potato Grower with Ten Percent Potash*; Concord.
- G 16. *Star Brand Superphosphate*; East Hardwick.

ROGERS AND HUBBARD CO., Middletown, Conn.

- C 5. *Complete Phosphate*; Coventry.
- G 5. *Grass and Grain Fertilizer*; Springfield.
- C 6. *New Market Garden Phosphate*; Coventry.
- G 4. *Oats and Top Dressing*; Bradford.
- C 3. *Bone Base Potato Phosphate*; Woodstock.
- C 2. *Soluble Corn and General Crop Manure*; Woodstock.
- C 4. *Soluble Potato Manure*; Woodstock.
- J 4. *Soluble Tobacco Manure*; Essex Center.

SANDERSON FERTILIZER AND CHEMICAL CO., New Haven, Conn.

- B 15. *Atlantic Coast Bone, Fish and Potash*; Fair Haven.
- A 16. *Corn Superphosphate*; Fair Haven.
- J 6. *Formula A*; Vergennes.
- B 16. *Potato Manure*; Fair Haven.
- G 6. *Special with Ten Percent Potash*; Fair Haven.

Special notice. The following brand licensed for sale in 1910 was not thus licensed in 1911:

Buffalo Fertilizer Co.'s Ideal Wheat and Corn.

The following brands were licensed but not found on sale:

Buffalo Fertilizer Co.: Fish Guano.

Lister's Agricultural Chemical Works: Grass and Oats Fertilizer.

Lowell (Swift's) Fertilizer Co.: Potato Grower.

New England Fertilizer Co.: Potato Grower.

CONCERNING THE TABLES ON PAGES 361-375

These tables, from the point of view of the execution of the law, form the essential part of the bulletin. Therein are displayed side by side what the fertilizer manufacturer says he will furnish and what he does furnish, the one in *italics*, the other in BLACK FACE. Furthermore all the details are given in order that the buyer may judge not only how much or how little plant food he gets for his money, but also how good or how inferior it is and what parts are good and what less good. While it is doubtless true that most buyers pay no attention whatsoever to the work of the control, many who have done so have profited thereby in getting a larger return in plant food for a dollar spent as a result of their study of the matter. And in order that such as may wish to grasp the full purport of these tables may be enabled to do so, there has been published from time to time brief explanatory matter, and, two years ago in bulletin 143, pages 183-192, a series of very full, almost painfully full, explanations of the meaning and significance of each piece of data. And there appears in this issue yet further explanation as to the nitrogen columns, this year for the first time thoroughly differentiated. This may be found on page 322.

In brief it may be said that the parallel BLACK FACE and *italics* columns are the most serviceable means of comparing promises and actualities, so far as the quantity of plant food is concerned; and that the other figures, exclusive of the valuation, help one to determine more particularly its quality.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water organic	Inactive water organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid	Round	Guaranteed	Valuation of potash†
Amer. Ag'l Chem. Co.																			
Grass & Lawn Topdress.	2.78	1.31	0.07	....	....	4.16	3.91	\$13.37	2.68	3.26	0.52	4.46	6	5.94	5	\$5.23	2.51	2	\$2.13
Grass & Oats Fertilizer	....	....	....	....	....	....	....	....	8.92	2.10	1.84	12.86	12	11.02	11	10.45	2.08	2	1.77
High Grade Ten Percent	1.27	0.35	0.30	0.43	0.23	2.58	2.47	9.02	4.44	2.44	1.50	8.88	7	6.88	6	6.55	10.17	10	8.64
N. W. Chal. Crop Grower	....	0.28	0.30	0.37	0.21	1.16	1.03	4.42	7.16	1.72	1.64	10.52	9	8.88	8	8.48	2.20	2	1.87
XXX Phos. & Potash	....	....	....	....	....	....	....	....	7.64	2.52	1.42	11.58	11	10.16	10	9.46	8.71	8	7.40
Bradley Fertilizer Co. brands																			
Alk. Bone and Potash	....	....	....	....	....	....	....	....	9.84	1.88	1.60	13.32	12	11.72	11	11.00	2.44	2	2.07
Complete Potato & Veg.	0.57	1.40	0.27	0.69	0.32	3.25	3.29	11.42	6.44	2.22	2.00	10.66	9	8.66	8	8.38	7.08	7	5.98
Complete Ten Percent	0.96	1.23	0.26	0.74	0.33	3.52	3.29	12.33	4.88	2.42	1.24	8.54	7	7.30	6	6.83	10.26	10	8.72
Corn Phosphate	0.45	0.78	0.41	0.35	0.20	2.19	2.06	7.78	5.60	3.04	1.78	10.42	9	8.64	8	8.18	1.59	1.5	1.35
Eclipse Phosphate	....	0.30	0.36	0.42	0.24	1.32	1.03	5.04	8.12	2.14	1.18	11.44	9	10.26	8	9.49	2.38	2	1.94
Green Mountain Special	0.46	0.67	0.19	0.37	0.17	1.86	1.65	6.54	6.56	2.46	1.08	10.10	9	9.02	8	8.30	5.60	5	4.76
H. G. Potato and Roots	0.56	0.81	0.18	0.51	0.25	2.31	1.65	8.14	5.24	3.70	1.22	10.16	9	8.94	8	8.17	10.09	10	8.58
Niagara Phosphate	....	0.63	0.24	0.30	0.15	1.32	0.82	4.78	6.44	2.00	1.50	9.94	8	8.44	7	8.00	1.62	1	1.37

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gen†	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid‡	Found	Guaranteed	Valuation of potash†
Amer. Ag'l Chem. Co.																			
Bradley Fertilizer Co. brands—Cont.																			
Potato Fertilizer	1.05	0.23	0.31	0.50	0.32	2.41	2.06	\$8.62	5.68	3.40	1.58	10.66	9.	9.08	8.	\$8.46	3.24	3.	\$2.75
Potato Manure	0.61	0.93	0.29	0.46	0.22	2.51	2.47	8.81	4.68	2.38	1.68	8.74	7.	7.06	6.	6.78	4.88	5.	4.19
Vermont	0.54	0.62	0.37	0.59	0.23	2.35	2.06	8.47	6.80	2.00	2.58	11.38	9.	8.80	8.	8.75	3.46	3.	2.94
XXL Superphosphate	0.44	0.72	0.24	0.92	0.42	2.74	2.47	10.03	7.72	2.24	1.54	11.50	10.	9.96	9.	9.36	2.58	2.	2.19
Clark's Cove Fertilizer Co. brands																			
Bay State Fertilizer G. G.	0.48	0.28	0.44	0.69	0.35	2.24	2.06	8.35	5.84	2.60	2.18	10.62	9.	8.44	8.	8.21	1.94	1.5	1.65
King Philip Alk. Guano	....	0.25	0.30	0.45	0.25	1.25	1.03	4.80	5.68	2.36	2.54	10.58	9.	8.04	8.	8.03	2.02	2.	1.72
Potato Fertilizer	....	0.77	0.37	0.68	0.37	2.19	2.06	8.14	6.36	2.28	1.98	10.62	9.	8.64	8.	8.33	3.33	3.	2.83
Cleveland Dryer Co. brands																			
Fertilizer for All Crops	....	0.25	0.36	0.32	0.19	1.12	1.03	4.28	5.36	3.24	1.76	10.36	9.	8.60	8.	8.11	2.11	2.	1.79
Potato Phosphate	0.42	0.88	0.29	0.40	0.24	2.23	2.06	7.88	6.28	2.12	1.42	9.82	9.	8.40	8.	7.92	3.12	3.	2.65
Superphosphate	0.40	0.93	0.33	0.42	0.20	2.28	2.06	8.06	5.76	2.70	1.72	10.18	9.	8.46	8.	8.03	1.53	1.5	1.30

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID								POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Round	Guaranteed	Valuation of potash†
Amer. Ag'l Chem. Co.																			
<i>Crocker Fertilizer & Chemical Co. brands</i>																			
Ammo. Corn Phosphate	0.51	0.40	0.31	0.64	0.33	2.19	2.06	\$8.03	6.36	2.54	1.72	10.62	9.	8.90	8.	\$8.44	1.69	1.5	\$1.44
New Rival Ammo. Super.	...	0.23	0.42	0.30	0.16	1.11	1.03	4.26	5.04	2.90	2.04	9.98	9.	7.94	8.	7.68	2.06	2.	1.75
Potato, Hop & Tobacco,	...	0.85	0.41	0.77	0.43	2.46	2.06	9.16	6.28	2.80	1.60	10.69	9.	9.08	8.	8.53	3.23	3.	2.75
Special Potato	0.76	1.52	0.54	0.48	0.25	3.55	3.29	12.41	4.12	2.60	1.52	8.24	7.	6.72	6.	6.40	10.66	10.	9.06
<i>Cumberland Bone Phosphate Co. brands</i>																			
Guano	...	0.39	0.32	0.32	0.20	1.33	1.03	4.61	6.24	2.56	1.22	10.02	9.	8.90	8.	8.16	2.18	2.	1.85
Potato Fertilizer	0.60	0.42	0.49	0.58	0.27	2.36	2.06	8.59	6.48	1.76	2.62	10.86	9.	8.24	8.	8.29	3.20	3.	2.72
Superphosphate	0.40	0.90	0.22	0.34	0.21	2.07	2.06	7.24	5.92	2.52	1.62	10.06	9.	8.44	8.	8.00	1.54	1.5	1.31
<i>Darling Fertilizer Co. brands</i>																			
Farm Favorite	0.95	0.35	0.27	0.47	0.28	2.32	2.06	8.24	6.80	2.42	1.60	10.82	9.	9.32	8.	8.70	3.22	3.	2.74
General Fertilizer	0.11	0.21	0.27	0.53	0.25	1.37	1.23	5.22	5.32	2.10	1.90	9.32	7.	7.42	6.	7.23	3.15	3.	2.68

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitrogen	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phosphoric acid†	Found	Guaranteed	Valuation of potash†
Amer. Ag'l Chem. Co.																			
East India Chemical Co. brands																			
Complete Potato Manure	1.56	0.72	0.28	0.65	0.23	3.44	3.29	\$11.94	4.24	2.74	2.08	9.06	7.	6.98	6.	\$6.84	10.08	10.	\$8.56
Harvest Home Fertilizer	...	0.13	0.14	0.38	0.31	0.96	1.03	3.74	6.20	2.76	2.08	11.04	9.	8.96	8.	8.62	2.00	2.	1.70
Standard UnXID Fert.	...	0.77	0.33	0.44	0.23	1.77	1.65	6.46	6.52	2.02	1.88	10.42	9.	8.54	8.	8.24	2.33	2.	1.98
Great Eastern Fertilizer Co. brands																			
Garden Special	1.17	0.95	0.23	0.68	0.34	3.37	3.29	11.78	6.72	2.30	1.48	10.50	9.	9.02	8.	8.48	7.47	7.	6.35
General Fertilizer	0.24	0.32	0.11	0.16	0.08	0.91	0.82	3.19	6.56	3.16	1.22	10.94	9.	9.72	8.	8.92	3.95	4.	3.36
Northern Corn Special	0.47	0.72	0.32	0.34	0.18	2.08	2.06	7.17	6.44	2.92	1.68	11.04	9.	9.56	8.	8.81	1.76	1.5	1.50
Potato Manure	0.91	0.23	0.35	0.63	0.30	2.42	2.06	8.77	6.64	2.22	2.30	11.16	9.	8.86	8.	8.68	3.20	3.	2.72
Pacific Guano Co. brands																			
Nobisque Guano	...	0.37	0.31	0.31	0.20	1.19	1.03	4.46	6.08	2.66	1.46	10.20	9.	8.74	8.	8.18	2.96	2.	1.92
Potato Special	0.37	1.00	0.28	0.41	0.24	2.30	2.06	8.10	5.88	3.08	1.04	10.00	9.	8.96	8.	8.16	3.16	3.	2.69
Soluble Pacific Guano	0.53	0.77	0.36	0.36	0.19	2.21	2.06	7.80	5.32	3.32	1.82	10.46	9.	8.64	8.	8.18	1.62	1.5	1.38

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitrogen	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phosphoric acid	Found	Guaranteed	Valuation of potash
Amer. Ag'l Chem. Co.																			
Quinnipiac Co. brands																			
Citmax Phosphate	....	0.21	0.13	0.41	0.22	0.97	1.03	\$3.71	5.52	2.40	2.16	10.08	9.	7.92	8.	\$7.76	2.09	2.	\$1.78
Corn Manure	....	1.03	0.34	0.61	0.25	2.23	2.06	8.10	6.76	1.82	2.00	10.58	9.	8.58	8.	8.34	1.54	1.5	1.31
Market Garden Manure	0.93	1.12	0.33	0.62	0.32	3.32	3.29	11.64	5.52	2.86	1.44	9.82	9.	8.88	8.	7.83	7.04	7.	5.98
Potato Phosphate	0.63	0.46	0.28	0.48	0.32	2.17	2.06	7.81	6.40	2.48	1.32	10.20	9.	8.88	8.	8.27	2.90	5.	2.47
Read Fertilizer Co. brands																			
Farmers' Friend Super.	....	1.16	0.40	0.48	0.22	2.26	2.06	8.11	6.64	2.12	1.80	10.56	9.	8.76	8.	8.40	3.16	5.	2.69
High Grade Far's Friend	0.70	1.51	0.48	0.41	0.22	3.32	3.29	11.51	5.08	2.24	1.32	8.64	7.	7.32	6.	6.89	10.56	10.	8.98
Leader Blood and Bone	0.30	0.42	0.24	0.22	0.14	1.32	0.82	4.70	5.16	2.48	1.42	9.06	8.	7.64	7.	7.19	1.44	1.	1.22
Potato Manure	....	1.16	0.32	0.68	0.37	2.53	2.47	9.19	5.24	1.58	1.56	8.88	7.	6.92	6.	6.60	10.26	10.	8.72
Practical Potato Special	....	0.21	0.41	0.43	0.25	1.30	0.82	5.03	3.44	1.92	2.48	7.84	5.	5.36	4.	5.63	6.46	8.	5.49
Standard Superphosphate	0.31	0.46	0.19	0.22	0.14	1.32	0.82	4.66	6.32	2.36	1.72	10.40	9.	8.68	8.	8.27	3.84	4.	3.26
Sure Catch Fertilizer	....	....	....	....	....	....	....	....	8.64	2.42	1.24	12.30	11.	11.06	10.	10.22	2.99	2.	2.54

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gen	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid	Found	Guaranteed	Valuation of potash
Amer. Ag'l Chem. Co.																			
H. F. Tucker Co. brands																			
Imperial for All Crops	....	0.18	0.18	0.42	0.19	1.14	1.03	\$3.74	6.24	2.10	2.24	10.58	9.	8.94	8.	\$8.20	2.08	2.	\$1.73
Imperial for Corn	....	0.28	0.40	0.36	0.19	1.28	1.03	4.70	5.36	2.70	2.24	10.30	9.	8.06	8.	7.88	2.30	2.	1.96
Imperial for Potatoes	....	0.28	0.35	0.32	0.29	1.07	1.03	4.74	5.32	2.86	2.10	10.28	9.	8.18	8.	7.92	2.00	2.	1.70
Williams & Clark Fertilizer Co. brands																			
Amer. Ammo. Bone	0.72	0.77	0.35	0.56	0.24	2.64	2.47	9.37	7.64	1.94	1.82	11.40	10.	9.58	9.	9.16	2.36	2.	2.01
Amer. Corn Phosphate	0.47	0.76	0.27	0.47	0.27	2.24	2.06	7.98	6.56	2.68	1.72	10.96	9.	9.24	8.	8.73	1.82	1.5	1.55
High Grade Spec. Pot. etc.	0.97	1.12	0.14	0.75	0.36	3.34	3.29	11.69	6.04	2.44	1.92	10.40	9.	8.48	8.	8.16	7.81	7.	6.64
Amer. Potato Manure	0.41	0.96	0.30	0.36	0.21	2.24	2.06	7.86	5.96	2.96	1.12	10.04	9.	8.92	8.	8.18	3.15	3.	2.68
Potato Phosphate	0.97	0.63	0.27	0.51	0.22	2.60	2.47	9.12	3.84	3.08	1.94	8.86	7.	6.92	6.	6.69	5.06	5.	4.30
Prolific Crop Producer	....	0.40	0.15	0.36	0.18	1.09	0.82	4.04	6.44	1.38	1.08	8.90	8.	7.82	7.	7.33	1.15	1.	0.98
Royal Bone Phosphate	....	0.30	0.36	0.32	0.20	1.18	1.03	4.48	5.68	2.58	2.02	10.28	9.	8.26	8.	7.98	2.05	2.	1.74

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water organic	Inactive water organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid	Round	Guaranteed	Valuation of potash
Armour Fertilizer Works																			
Complete Manure	1.40	0.77	0.18	0.49	0.56	3.40	3.5	\$11.86	4.64	1.96	1.90	8.50	8	6.60	6	\$6.51	*9.53	10.	\$8.87
Corn Special	0.91	0.11	0.13	0.33	0.36	1.84	1.65	6.54	6.44	1.74	1.26	9.44	8.5	8.18	8	7.69	5.02	5.	4.27
General Farm	0.28	0.11	0.19	0.36	0.40	1.84	0.82	5.05	6.64	2.14	2.06	10.84	8.5	8.78	8	8.51	3.50	3.	2.98
High Grade Potato	0.96	0.13	0.17	0.26	0.43	1.95	1.65	6.93	6.68	2.00	1.74	10.42	8.5	8.68	8	8.31	*9.79	10.	9.36
Oats and Clover Special	...	...	...	...	...	...	...	...	8.00	2.16	1.02	11.18	10.5	10.16	10.	9.34	7.89	8.	6.71
Bowker Fertilizer Co.																			
Corn Phosphate	0.33	0.53	0.27	0.40	0.24	1.77	1.65	6.39	6.16	2.40	2.22	10.78	9	8.56	8	8.35	2.16	2.	1.84
Early Potato Manure	1.62	0.75	0.25	0.57	0.25	3.44	3.29	11.84	6.16	2.50	2.34	11.00	9.	8.66	8	8.47	7.56	7.	6.43
Hill and Drill Phosphate	0.50	0.90	0.32	0.70	0.27	2.69	2.47	9.64	6.84	3.30	1.76	11.90	10.	10.14	9	9.50	2.32	2.	1.97
Market Garden Fertilizer	0.55	0.96	0.34	0.52	0.21	2.58	2.47	9.11	4.52	2.38	1.88	8.78	7.	6.90	6	6.72	9.96	10.	8.47
Potash Bone	...	0.18	0.38	0.26	0.18	1.00	0.82	3.86	4.52	3.42	1.34	9.28	7.	7.94	6	7.35	2.22	2.	1.89

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN					PHOSPHORIC ACID					POTASH								
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid	Found	Guaranteed	Valuation of potash†
Bowker Fertilizer Co.																			
Potash or Staple Phos.	...	0.21	0.38	0.26	0.19	1.04	0.82	\$3.99	5.24	3.40	1.84	10.48	9.	8.64	8.	\$8.18	3.37	3.	\$2.86
Potato and Veg. Fert.	0.35	0.95	0.42	0.58	0.32	2.63	2.47	9.44	4.76	4.64	1.66	11.06	9.	9.40	8.	8.65	5.52	4.	4.69
Potato and Veg. Phos.	...	0.32	0.53	0.77	0.40	2.02	1.65	7.82	6.52	2.42	2.04	10.98	9.	8.94	8.	8.63	2.07	2.	1.76
Soluble Potash	...	...	...	...	...	...	...	...	7.72	2.74	1.72	12.18	11.	10.46	10.	9.83	7.01	8.	5.96
Square Brand Bone & Pot.	0.10	0.18	0.20	0.81	0.33	1.63	1.64	6.26	5.04	2.24	2.58	9.86	7.	7.28	6.	7.37	2.04	2.	1.73
Stockbridge Corn & Grain	1.10	1.68	0.03	0.42	0.20	3.43	3.29	11.50	7.32	2.84	1.80	11.96	11.	10.16	10.	9.58	7.38	7.	6.19
Stockbridge Pot. Manure	2.07	0.18	0.51	0.40	0.23	3.39	3.29	11.76	4.56	2.60	1.28	8.44	7.	7.16	6.	6.70	10.77	10.	9.15
Stockbridge Seed Down	...	1.30	0.36	0.67	0.36	2.69	2.47	9.72	4.08	2.94	2.12	9.14	9.	7.02	6.	6.87	10.55	10.	8.97
Stockbridge Top Dressing	1.00	0.72	0.58	2.02	0.79	5.11	4.94	19.06	3.16	1.54	0.98	5.68	6.	4.70	4.	4.46	6.06	6.	5.15
Superphos. with Potash	...	...	...	...	...	...	...	...	9.00	1.50	1.64	12.14	11.	10.50	10.	9.96	2.92	2.	2.40
Sure Crop Phosphate	...	0.35	0.23	0.28	0.19	1.05	0.82	3.92	6.04	2.92	1.28	10.24	9.	8.96	8.	8.29	2.17	2.	1.84
Vt. Grange Ch. D. Brand	0.98	0.21	0.33	0.57	0.35	2.44	2.06	8.81	6.60	2.52	2.02	11.14	9.	9.12	8.	8.77	3.05	3.	2.59

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro-Gen†	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phosphoric acid†	Found	Guaranteed	Valuation of potash†
J. F. Bromley																			
Banner Brand	0.15	1.87	0.26	0.80	0.43	3.51	3.29	\$12.42	6.76	2.00	0.90	9.66	8.5	8.76	8.	\$8.04	19.09	9.	\$8.34
Corn and Potato	0.52	0.18	0.25	0.28	0.33	1.56	1.23	5.68	7.40	1.38	0.80	9.58	9.	8.78	8.5	8.08	2.96	2.5	2.52
Grass and Grain	...	...	...	...	...	...	...	...	8.12	2.28	0.46	10.86	10.5	10.40	10.	9.31	2.46	2.	2.09
Green Mountain Brand	0.41	0.14	0.21	0.59	0.39	1.74	1.23	6.52	5.24	2.24	2.32	9.80	8.5	7.48	8.	7.44	5.59	5.	4.75
Potato Special	0.11	0.70	0.22	0.36	0.33	1.72	1.65	6.23	5.60	2.76	1.44	9.80	8.5	8.36	8.	7.83	19.84	10.	8.73
Special Corn Fertilizer	0.37	...	0.27	0.17	0.33	1.14	0.82	4.26	5.28	2.96	2.60	10.84	8.	8.94	7.5	8.16	3.28	3.	2.79
Special Potato Fertilizer	0.33	...	0.31	0.19	0.35	1.18	0.82	4.46	5.24	2.88	2.62	10.74	8.	8.12	7.5	8.07	3.27	3.	2.78
Buffalo Fertilizer Co.																			
Celery and Potato Special	0.88	0.14	0.23	0.54	0.26	2.05	1.6	7.38	6.36	2.58	1.68	10.62	9.	8.94	8.	8.45	9.81	10.	8.34
Extra Phos. and Potash	...	...	...	...	...	...	...	...	6.88	3.50	1.26	11.64	11.	10.38	10.	9.49	8.04	8.	6.83
Farmers' Choice	...	0.67	0.02	0.21	0.21	1.11	0.8	3.90	4.28	4.16	0.88	9.32	9.	8.44	8.	7.52	4.98	5.	4.19
General Crop	...	...	...	...	...	...	...	...	4.64	4.06	0.87	9.56	10.	8.69	9.	7.77	3.36	3.	2.86

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308. ‡Potash partly as sulphate.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water organic	Inactive water organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash‡
Buffalo Fertilizer Co.																			
High Grade Manure	2.05	0.14	0.19	0.55	0.25	3.18	3.3	\$10.97	4.72	3.40	1.68	9.90	8.	8.12	7.	\$7.64	10.08	10.	\$8.57
New England Special	0.10	1.40	0.08	0.19	0.14	1.91	1.6	6.44	3.12	6.72	0.90	10.74	10.	9.84	9.	8.55	5.51	5.	4.68
Burlington Rendering Co.																			
Animal Fertilizer	0.15	0.70	0.44	0.62	0.57	2.48	2.	9.24	1.80	3.50	2.54	7.94	7.	5.30	4.	5.43	5.19	4.	4.41
Special Potato	....	1.23	0.33	0.48	0.54	2.58	2.46	9.34	3.84	3.18	1.12	8.14	8.	7.02	5.	6.45	6.52	6.	5.54
Coe-Mortimer Co.																			
Columbian Corn & Pot.	0.79	0.32	0.11	0.14	0.14	1.50	1.23	5.11	6.04	2.36	1.14	9.54	9.5	8.40	8.5	7.79	2.67	2.5	2.27
Extra Special Potato	....	1.11	0.21	0.24	0.23	1.79	1.65	6.27	6.05	1.92	1.09	9.06	9.	7.97	8.	7.42	9.38	10.	7.99
Gold Brand Excel. Guano	0.82	1.16	0.13	0.18	0.29	2.58	2.47	8.74	6.56	1.36	0.67	8.59	9.	7.92	8.	7.26	5.89	6.	5.01
H. G. Ammo. Bone Super.	0.83	0.49	0.15	0.30	0.32	2.09	1.85	7.30	5.64	2.46	1.44	9.54	9.	8.10	8.	7.63	3.54	3.	3.01
N. E. Corn and Potato	....	0.53	0.20	0.18	0.19	1.10	0.8	3.98	5.04	3.20	1.12	9.36	8.5	8.24	7.5	7.55	2.95	2.	2.51
Prize Br. Grass and Grain	....	....	....	....	....	....	....	....	7.72	2.28	1.14	11.14	11.	10.00	10.	9.23	2.06	2.	1.75

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitrogen	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phosphoric acid†	Found	Guaranteed	Valuation of potash‡
Coe-Mortimer Co.																			
Spec. Pot. & Fruit Grower	0.88	0.46	0.11	0.25	0.28	1.98	1.65	\$6.78	4.76	2.86	1.24	8.86	9.	7.62	8.	\$7.07	4.06	4.	\$3.45
Standard Potato Fertilizer	0.65	1.23	0.43	0.44	0.50	3.25	3.3	11.50	4.60	1.46	1.14	7.20	7.	6.06	6.	5.77	10.22	10.	8.69
Essex Fertilizer Co.																			
A1 Superphosphate	...	...	0.72	0.43	0.22	1.37	1.2	5.48	4.24	3.26	1.08	8.58	8.	7.50	7.	6.86	2.25	2.	1.91
Complete for Corn & Grain	...	1.30	1.22	0.74	0.37	3.63	3.28	13.48	5.52	1.38	0.76	7.66	7.	6.90	6.	6.37	9.85	10.	8.37
Complete for Potatoes, etc.	...	1.65	0.46	1.04	0.41	3.56	3.28	12.92	7.04	0.36	0.46	7.96	7.	7.40	6.	6.81	10.14	10.	8.62
Grain and Grass	...	...	0.41	0.35	0.21	0.97	0.82	3.88	6.24	2.44	1.82	10.50	9.	8.68	8.	8.30	4.10	4.	3.49
Market Garden & Potato	...	0.53	0.55	0.75	0.30	2.13	2.	8.10	7.04	1.50	0.74	9.28	9.	8.54	8.	7.84	5.14	5.	4.37
XXXX Fish and Potash	...	0.53	0.98	0.62	0.30	2.43	2.	9.30	5.96	2.60	1.12	9.68	9.	8.56	8.	7.89	3.36	3.	2.86
Lister's Ag'l Chem. Works																			
G Brand	...	0.18	0.26	0.29	0.27	1.00	0.82	3.84	6.76	1.80	1.24	9.80	9.	8.56	8.	8.02	4.01	4.	3.41
Grass and Grain Fert.	...	...	...	...	...	...	...	...	8.64	1.88	0.62	11.14	11.	10.52	10.	9.53	2.92	2.	1.89

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gen†	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Round	Guaranteed	Valuation of potash‡
Lister's Ag'l Chem. Works																			
Onelda Special		0.16	0.31	0.32	0.30	1.09	0.82	\$4.23	5.88	1.56	1.28	8.72	9.	7.44	7.	\$7.05	1.07	1.	\$0.91
Potato Manure	0.72	1.26	0.44	0.61	0.43	3.46	3.29	12.26	7.24	1.12	1.44	9.80	9.	8.56	8.	8.00	7.90	7.	6.72
Special Corn Fertilizer		0.21	0.55	0.39	0.32	1.47	1.23	5.71	6.60	2.10	1.02	9.72	9.	8.70	8.	8.03	8.96	3.	2.77
Special Potato Fertilizer		0.21	0.63	0.63	0.50	1.97	1.65	7.71	6.84	1.38	1.84	10.06	9.	8.22	8.	8.00	8.34	3.	2.84
Special Ten Percent Pot.		0.63	0.48	0.51	0.43	2.06	1.65	7.70	7.12	1.32	0.92	9.36	9.	8.44	8.	7.84	10.08	10.	8.57
Success Fertilizer	0.12	0.18	0.60	0.35	0.31	1.56	1.23	6.00	7.56	2.04	1.04	10.64	10.	9.60	9.	8.85	2.28	2.	1.94
Lowell (Swift's) Fert. Co.																			
Animal Brand		1.16	0.71	0.48	0.25	2.60	2.46	9.47	6.20	2.30	0.30	8.80	9.	8.50	8.	7.54	4.08	4.	3.43
Bone Fert. for Corn & Gr.			0.94	0.45	0.24	1.63	1.64	6.52	5.56	3.00	0.76	9.32	9.	8.56	8.	7.70	2.78	3.	2.36
Cereal Fertilizer		0.11	0.52	0.33	0.23	1.19	0.82	4.67	5.92	2.02	0.92	8.86	8.	7.94	7.	7.32	1.09	1.	0.93
Empress Brand		0.11	0.74	0.37	0.21	1.43	1.25	5.63	4.04	3.64	1.38	9.06	8.	7.68	7.	7.10	1.78	2.	1.51
Potato Manure		0.49	0.49	0.60	0.26	1.84	1.64	6.97	5.08	2.08	0.78	7.94	8.	7.16	7.	6.54	4.24	4.	3.60

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gen†	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid‡	Found	Guaranteed	Valuation of potash‡
Lowell (Swift's) Fertilizer Co.																			
Potato Phosphate		1.12	0.57	0.61	0.28	2.58	2.46	\$9.42	7.88	0.72	0.48	9.08	9.	8.60	8.	\$7.86	6.01	6.	\$5.11
Special Corn & Vegetable		1.61	0.80	0.70	0.32	3.43	3.28	12.43	5.44	3.12	0.72	9.28	9.	8.56	8.	7.69	7.42	7.	6.31
Special Potato Fertilizer		1.28	0.36	0.73	0.28	2.65	2.4	9.58	5.34	1.68	0.72	7.74	7.	7.02	6.	6.44	10.42	10.	8.86
Sterling Phosphate			0.50	0.38	0.21	1.09	0.82	4.36	5.32	2.88	1.86	10.06	9.	8.20	8.	7.83	4.08	4.	3.43
Superior Phosphate		1.33	1.19	0.84	0.43	3.79	3.69	14.10	5.48	2.04	0.56	8.08	8.	7.52	7.	6.78	9.90	10.	8.42
New England Fertilizer Co.																			
Complete Manure		1.23	0.95	0.84	0.42	3.44	3.28	12.78	3.96	2.50	0.84	7.30	7.	6.46	6.	5.90	10.26	10.	8.72
Corn & Grain Fertilizer		0.11	0.80	0.34	0.22	1.47	1.23	5.79	4.76	2.98	1.02	8.76	8.	7.74	7.	7.07	2.02	2.	1.72
Corn Phosphate		0.16	1.09	0.42	0.26	1.93	1.64	7.59	5.76	2.72	1.24	9.72	9.	8.48	8.	7.86	3.38	3.	2.87
Superphosphate		1.30	0.61	0.55	0.21	2.67	2.46	9.64	6.92	1.60	0.66	9.18	9.	8.52	8.	7.77	4.26	4.	3.62
Peerless Fertilizer			0.42	0.23	0.21	0.86	0.82	3.44	4.68	2.78	0.84	8.30	8.	7.46	7.	6.77	1.11	1.	0.94
Potato Fertilizer		0.39	0.56	0.49	0.26	1.70	1.64	6.49	5.28	2.02	0.58	7.88	8.	7.30	7.	6.60	4.06	4.	3.45

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid	Round	Guaranteed	Valuation of potash
Parmenter & Polsey Fert. Co.																			
Corn and Grain Fertilizer																			
...	...	0.47	0.40	0.22	1.09	0.82	\$4.36	6.80	2.18	1.72	10.70	9.	8.96	8.	\$8.55	4.13	4.	\$3.51	
...	0.11	0.69	0.31	0.22	1.33	1.23	5.23	4.24	2.84	1.04	8.12	8.	7.08	7.	6.51	2.18	2.	1.81	
Plymouth Rock Fertilizer																			
...	1.30	0.67	0.42	0.26	2.65	2.46	9.56	7.52	1.66	0.86	10.04	9.	9.18	8.	8.44	4.01	4.	3.41	
Potato Fertilizer																			
...	0.53	0.61	0.36	0.27	1.77	1.64	6.66	5.36	1.36	0.82	7.54	7.	6.72	6.	6.24	6.35	6.	5.40	
Pot. Grower with 10% Pot.																			
...	1.17	0.48	0.73	0.28	2.66	2.46	9.70	5.56	0.82	0.86	7.24	7.	6.38	6.	6.00	10.12	10.	8.60	
Star Brand Superphos.																			
...	0.46	0.52	0.60	0.34	1.92	1.64	7.31	6.40	1.05	0.47	7.92	8.	7.45	7.	6.79	4.05	4.	3.44	
Rogers & Hubbard Co.																			
Complete Phosphate																			
0.67	...	0.41	0.47	0.28	1.88	1.5	6.78	4.68	3.42	2.28	10.38	8.	8.10	7.	7.86	5.49	5.	4.67	
Grass and Grain Fert.																			
0.40	0.18	0.33	0.96	0.50	2.37	2.2	9.02	0.04	9.71	6.04	15.79	16.	9.75	6.5	10.23	11.31	10.	10.04	
New Market Gard. Fert.																			
1.27	...	0.40	0.49	0.28	2.44	2.	8.74	3.56	3.30	2.14	9.00	7.	6.86	6.	6.70	10.15	10.	8.63	
Oats and Top Dressing																			
7.58	...	0.37	0.36	0.20	8.51	8.5	27.98	0.24	4.58	3.46	8.28	8.	4.82	4.5	5.26	10.17	8.	8.64	

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gen	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid	Round	Guaranteed	Valuation of potash
Rogers & Hubbard Co.																			
Potato Phosphate	1.14	....	0.22	0.47	0.31	2.14	2.	\$7.65	6.08	3.88	2.22	12.18	10.	9.96	9.	\$9.46	6.13	5.	\$5.21
Sol. Corn and Gen. Crops	1.31	0.11	0.62	0.52	0.33	2.89	2.5	9.42	2.36	4.78	2.50	9.64	8.	7.14	6.	6.94	8.81	8.	7.49
Soluble Potato Manure	2.00	0.23	0.77	1.54	0.60	5.14	5.	18.78	0.84	7.30	3.94	12.08	10.	8.14	7.	8.18	*5.71	5.	5.54
Soluble Tobacco Manure	2.11	0.25	0.80	1.50	0.53	5.19	5.	18.87	1.20	6.00	4.30	11.50	10.	7.20	7.	7.60	*10.19	10.	10.05
Sanderson Fert. & Chem. Co.																			
Atlantic Bone, Fish & Pot.	....	0.25	0.76	0.70	0.50	2.21	1.67	8.64	2.00	3.34	1.22	6.56	6.	5.34	5.	4.96	4.38	4.	3.72
Corn Superphosphate	0.18	0.11	0.82	0.71	0.46	2.28	1.67	8.89	5.20	3.50	1.52	10.22	9.	8.70	7.	8.09	2.94	2.	2.50
Formula A	....	2.14	0.55	0.43	0.23	3.35	3.33	11.67	5.96	1.28	1.60	8.84	9.	7.24	6.	7.02	6.08	6.	5.13
Potato Manure	....	0.56	0.65	0.66	0.41	2.28	1.67	8.67	3.16	3.52	1.32	8.00	8.	6.68	5.	6.19	6.22	6.	5.29
Special Ten Percent	0.84	1.02	0.54	0.60	0.33	3.33	2.47	11.83	4.88	2.24	0.90	8.02	8.	7.12	5.	6.54	11.30	10.	9.61

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 308.

VI. ANALYSES OF FERTILIZERS FOR FIVE YEARS, 1907-1911

The buyer of mixed goods usually makes his choice before the analyses are published. The Station usually prints its bulletin in mid-June or early July. This date is well in advance of the issuance of similar figures by other northern stations, yet the information they convey usually reaches the buyer too late to be of service; and if station analyses are consulted at all, those of former years are used. These may or may not be safe guides. If, however, reference to analyses of successive years shows essential uniformity of composition in the past and an unchanged guaranty, the buyer is safe in assuming that the former figures will be applicable. If the guaranty statement has been changed, and if former statements have been lived up to in the past, the presumption is in favor of similar keeping of promises for the present year.

In order to facilitate such reference and to indicate something of the evenness or variation in composition from year to year of the several brands, tables are given herewith showing the nitrogen, available phosphoric acid and potash percentages for the past five years of 159 of the 161 licensed brands.¹ The guaranties printed in the tables are those for 1911 as well as for 1907-1910 with a few exceptions, which are foot-noted. The * indicates that sulphate of potash was used as a source of potash, the †, that 0.20 percent or more of nitrogen was present either as nitrate of soda or as sulphate of ammonia or both.

These tables, containing the essentials of five years' inspection, ought to prove helpful in choosing fertilizers, particularly when they are bought early in the season.

¹Two brands licensed this year not found on sale.

ANALYSES OF LICENSED FERTILIZERS—1907-1911

BRAND	NITROGEN					AVAILABLE PHOSPHORIC ACID					POTASH				
	1907	1908	1909	1910	1911	1907	1908	1909	1910	1911	1907	1908	1909	1910	1911
Grass and Lawn Top Dress.	3.82	5.40	4.23	4.56	4.16	3.91	5.50	6.90	5.94	5.80	5.94	2.85	4.49	3.14	3.24
Grass and Oats Fertilizer.	.....	.....	.....	.....	.....	.....	.....	.....	12.13	11.78	11.02	.....	.....	1.95	2.14
High Grade Ten Percent...	2.74	2.37	3.30	2.99	2.58	2.47	6.32	6.00	6.81	5.75	6.88	10.75	9.88	10.08	10.17
No. West Chal. Crop. Grow.	.....	.....	1.18	1.46	1.16	1.03	.....	.....	9.99	8.44	8.88	.....	.....	2.36	2.39
XXX Phosphate & Potash	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.32	10.16	.....	.....	.....	10.59
Bradley's Alkaline Bone	.....	.....	.....	.....	.....	.....	11.30	10.32	11.57	10.84	11.72	2.38	1.91	2.20	2.52
Bradley's Comp. Pot. Veg.	4.00	3.49	3.30	3.62	3.25	3.3	8.20	8.68	7.64	7.84	8.66	7.88	6.73	6.90	6.90
Bradley's Comp. 10 Per't.	3.58	3.47	3.26	3.65	3.52	3.3	6.66	6.78	7.50	5.34	7.30	11.24	10.25	9.98	10.09
Bradley's Corn Phosphate	2.14	2.17	2.60	2.30	2.19	2.06	8.52	8.36	9.39	8.52	8.64	1.84	1.90	2.17	1.91
Bradley's Eclipse Phos....	1.33	0.90	1.31	1.39	1.32	1.03	7.99	9.30	9.58	8.26	10.26	2.04	2.12	2.48	2.74
Bradley's Gn. Mt. Special	.....	.....	.....	2.14	1.86	1.65	.....	.....	.....	9.26	9.02	.....	.....	.....	5.10
Bradley's H.G. Pot. & Root	....	.....	.....	2.46	2.31	1.65	.....	.....	.....	8.96	8.94	.....	.....	.....	8.44
Bradley's Niagara Phos....	1.23	1.12	1.12	1.19	1.32	0.82	7.66	7.98	8.01	9.22	8.44	1.31	1.45	1.68	2.26
Bradley's Potato Fertilizer	2.10	1.98	2.17	2.30	2.41	2.06	8.14	8.30	9.42	9.00	9.08	3.36	3.36	2.97	3.16
Bradley's Potato Manure...	2.63	2.83	2.91	3.47	2.51	2.47	7.94	6.88	6.08	6.12	7.06	5.40	6.78	4.98	7.88
Bradley's Vermonter	2.32	2.21	2.42	2.32	2.35	2.06	8.38	8.18	8.34	9.00	8.80	3.35	3.11	3.09	3.35

*Potash in brands thus marked is largely if not entirely sulphate, †Contained 0.20 percent or more of mineral nitrogen.

ANALYSES OF LICENSED FERTILIZERS—1907-1911

BRAND	NITROGEN					AVAILABLE PHOSPHO'IC ACID					POTASH							
	1907	1908	1909	1910	1911	Guar	1907	1908	1909	1910	1911	Guar	1907	1908	1909	1910	1911	Guar
	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†
Bradley's XL Superphos...	2.70	2.95	2.46	2.86	2.74	2.47	9.00	9.08	9.24	9.98	9.96	2.33	2.71	2.28	2.74	2.58	2.	2.
Clark's Cove Bay State G.G.	2.53	2.14	2.32	2.21	2.24	2.06	9.23	8.38	7.98	9.20	8.44	1.98	1.65	1.88	1.79	1.94	1.5	1.5
Clark's Cove King Philip...	1.33	1.26	1.26	1.26	1.25	1.03	8.06	8.38	8.34	8.96	8.04	2.16	2.06	2.22	2.32	2.02	2.	2.
Clark's Cove Potato Fert...	2.39	2.10	2.39	2.30	2.19	2.06	8.78	8.56	8.10	9.66	8.64	3.18	3.50	3.27	3.33	3.33	3.	3.
Cleveland Fertilizer.....	1.23	1.37	1.14	1.23	1.12	1.03	8.38	8.78	9.30	9.88	8.60	2.03	2.20	2.24	2.19	2.11	2.	2.
Cleveland Potato Phos.....	2.10	2.14	2.24	2.05	2.23	2.06	8.18	8.26	9.16	9.70	8.40	3.85	3.21	3.47	3.47	3.12	3.	3.
Cleveland Superphosphate.	2.10	2.17	2.24	2.25	2.28	2.06	8.06	8.08	8.66	9.44	8.46	1.80	1.92	2.12	1.92	1.53	1.5	1.5
Crocker's Am. Corn Phos...	2.07	2.01	2.35	2.48	2.19	2.06	8.02	8.14	9.10	8.24	8.90	1.92	2.25	1.90	1.80	1.69	1.5	1.5
Crocker's N. Rival Ammo...	1.16	1.16	1.16	1.42	1.11	1.03	8.04	8.82	9.34	8.56	7.94	1.95	2.05	2.21	2.40	2.06	2.	2.
Crocker's Pot., Hop & Tob.	2.10	2.05	2.28	2.34	2.46	2.06	7.87	7.68	9.09	9.10	9.08	3.78	3.22	3.19	3.40	3.23	3.	3.
Crocker's Special Potato....	3.30	3.33	3.75	3.67	3.55	3.5	7.32	6.08	7.58	5.66	6.72	9.84	10.44	9.84	10.04	10.66	10.	10.
Cumberland Guano.....	.....	.....	1.37	1.25	1.23	1.03	.....	.....	8.70	10.04	8.80	.....	.....	1.93	2.27	2.18	2.	2.
Cumberland Potato Fert....	2.17	1.95	2.24	2.48	2.36	2.06	7.74	8.66	9.24	8.80	8.24	3.10	3.78	3.36	3.36	3.20	3.	3.
Cumberland Superphos....	2.24	2.14	2.32	2.39	2.07	2.05	8.00	7.98	8.68	9.26	8.44	1.87	1.82	2.32	1.69	1.54	1.5	1.5
Darling's Farm Favorite....	2.21	2.05	2.24	2.10	2.32	2.06	8.12	7.96	8.66	10.32	9.22	3.32	3.01	3.17	3.50	3.22	3.	3.
Darling's General Fert.....	.....	.....	1.68	1.56	1.87	0.82	.....	.....	7.58	8.05	7.42	.....	.....	4.18	3.33	3.15	4.	4.

*Potash in brands thus marked is largely if not entirely sulphate. †Contained 0.20 percent or more of mineral nitrogen.

ANALYSES OF LICENSED FERTILIZERS—1907-1911

BRAND	NITROGEN					AVAILABLE PHOSPHORIC ACID					POTASH							
	1907	1908	1909	1910	1911	Guar	1907	1908	1909	1910	1911	Guar	1907	1908	1909	1910	1911	Guar
E. Ind. Complete Potato...	3.37	3.44	3.40	3.60	3.44	3.3	7.34	6.36	6.86	6.46	6.98	6.	10.48	9.87	10.18	10.20	10.08	10.
E. Ind. Harvest Home.....	1.30	1.12	1.26	1.32	0.96	1.03	8.04	8.06	9.28	8.76	8.96	8.	2.00	2.00	2.24	2.14	2.00	2.
E. Ind. Standard UnXID..	1.82	1.51	1.75	1.89	1.77	1.65	9.04	8.04	9.60	8.80	8.54	8.	2.04	2.24	2.35	2.59	2.33	2.
Great East. Garden Special	3.30	3.65	3.56	3.76	3.37	3.3	8.00	8.18	7.12	8.54	9.02	8.	7.10	7.26	7.63	7.99	7.47	7.
Great East. General Fert...	1.09	1.44	1.18	1.25	0.91	0.82	8.08	7.70	7.99	8.96	9.72	8.	4.03	5.09	4.05	3.92	3.95	4.
Great East. No. Corn Spec.	2.60	2.21	2.28	2.46	2.03	2.06	8.60	8.40	8.47	9.20	9.36	8.	1.72	1.89	1.75	1.88	1.76	1.5
Great East. Potato Manure	2.24	2.17	2.17	2.23	2.42	2.06	8.18	8.20	8.61	9.42	8.86	8.	3.44	3.20	3.04	3.18	3.20	3.
Pac. Gu. Co.'s Nobesque Gu.	1.30	1.37	1.11	1.23	1.19	1.03	8.15	8.74	9.56	9.24	8.74	8.	2.02	2.02	2.02	2.15	2.26	2.
Pac. Gu. Co.'s Potato Spec.	2.39	2.07	2.24	2.16	2.30	2.06	8.08	8.28	8.14	9.50	8.96	8.	3.02	3.22	3.34	3.38	3.16	3.
Pac. Gu. Co.'s Sol. Pac. Gu.	2.56	2.14	2.10	2.46	2.21	2.06	8.02	8.70	8.00	9.40	8.64	8.	1.62	1.98	1.77	1.95	1.62	1.5
Quinnipiac Climax Phos....	1.26	1.37	1.35	1.33	0.97	1.03	7.84	8.84	8.38	7.82	7.92	8.	1.94	1.99	2.36	2.58	2.09	2.
Quinnipiac Corn Manure....	2.24	2.05	2.17	2.36	2.23	2.06	8.16	8.18	9.03	8.38	8.58	8.	1.80	2.08	2.18	1.70	1.54	1.5
Quinnipiac Market Garden	4.07	3.40	3.39	3.53	3.32	3.3	7.99	8.03	8.26	8.16	8.38	8.	7.84	6.96	7.72	6.87	7.04	7.
Quinnipiac Potato Phos....	2.21	2.07	2.24	2.28	2.17	2.06	8.30	8.50	9.09	8.92	8.88	8.	3.12	3.28	3.08	3.44	2.90	3.
Read's Farmers' Friend....	2.24	1.81	2.28	2.16	2.26	2.06	8.26	8.30	8.78	9.58	8.76	8.	3.30	3.62	3.18	3.58	3.16	3.
Read's H. G. F.'s Friend...	3.72	3.12	3.32	3.54	3.32	3.3	6.56	6.30	6.85	5.25	7.32	6.	11.27	10.47	10.06	10.67	10.56	10.

*Potash in brands thus marked is largely if not entirely sulphate. †Contained 0.20 percent or more of mineral nitrogen.

ANALYSES OF LICENSED FERTILIZERS—1907-1911

BRAND	NITROGEN					AVAILABLE PHOSPHO'C ACID					POTASH							
	1907	1908	1909	1910	1911	Guar.	1907	1908	1909	1910	1911	Guar.	1907	1908	1909	1910	1911	Guar.
Read's Leader Bl. and Bone	1.16	1.19	1.12	1.40	1.32	0.82	7.02	8.28	7.38	7.90	7.64	7.	1.39	1.32	1.02	2.53	1.44	1.
Read's Potato Manure	.....	.....	.....	2.80	2.53	2.47	.....	.....	.....	5.98	6.82	6.	.....	.....	.....	9.76	10.26	10.
Read's Prac. Potato Spec'l	1.26	1.51	1.04	1.81	1.30	0.82	6.99	7.24	7.44	8.72	5.36	4.	8.08	10.03	8.08	9.21	6.46	3.
Read's Standard Superphos	1.09	1.47	1.16	1.41	1.32	0.82	8.08	7.67	8.20	8.08	8.68	3.	4.09	5.07	4.09	4.61	3.84	4.
Read's Sure Catch Fert.....	.....	.....	.....	.....	.....	.....	10.88	10.06	11.99	11.24	11.06	10.	2.22	1.57	2.10	2.02	2.99	2.
Tucker's Imperial all Crops	1.33	1.07	1.30	1.47	1.14	1.03	8.50	9.66	9.19	9.46	8.34	3.	2.30	2.22	2.59	2.24	2.03	2.
Tucker's Imperial Corn.....	1.26	0.88	1.33	1.23	1.23	1.03	8.16	9.56	8.64	9.04	8.06	3.	2.14	2.17	2.04	2.08	2.30	2.
Tucker's Imperial Potato...	1.23	1.12	1.47	1.25	1.07	1.03	8.02	9.70	8.54	9.16	8.18	3.	2.09	2.31	2.30	2.04	2.00	2.
W. & Cl. Am. Bone Phos...	.....	.....	.....	.....	2.64	2.47	.....	.....	.....	.....	9.58	9.	.....	.....	.....	.....	2.36	2.
W. & Cl. Am. Corn Phos...	2.60	1.96	2.14	2.35	2.24	2.06	8.56	8.48	8.85	9.84	9.24	3.	2.04	1.79	2.09	2.46	1.82	1.5
W. & Cl. Am. H. G. Sp. Pot	3.40	3.44	3.35	3.60	3.34	2.3	8.28	8.01	8.12	7.70	8.48	3.	7.03	7.26	6.77	6.72	7.81	7.
W. & Cl. Am. Potato Man.	2.32	2.10	2.28	2.23	2.24	2.06	8.08	8.16	9.16	10.20	8.92	3.	3.79	3.15	3.38	3.66	3.15	3.
W. & Cl. Potato Phos.	2.95	2.74	2.79	2.93	2.60	2.5	7.40	7.28	6.37	8.01	6.92	6.	6.86	5.60	4.84	5.55	5.06	5.
W. & Cl. Prolific Crop Pro.	1.12	1.37	1.19	1.42	1.09	0.82	8.20	8.14	7.50	7.82	7.82	7.	2.00	1.25	1.67	2.87	1.15	1.
W. & Cl. Royal Bone Phos.	1.26	1.33	1.26	1.35	1.18	1.03	8.42	8.80	9.09	8.77	8.26	3.	2.00	1.95	2.03	2.06	2.06	2.

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ANALYSES OF LICENSED FERTILIZERS—1907-1911

BRAND	NITROGEN					AVAILABLE PHOSPHO'IC ACID					POTASH							
	1907	1908	1909	1910	1911	Guar.	1907	1908	1909	1910	1911	Guar.	1907	1908	1909	1910	1911	Guar.
Armour's Complete Manure	.....	.....	3.21	3.66	3.40	3.3	.....	.....	6.52	6.60	6.60	6.	.....	.....	10.14	10.44	9.53	10.
Armour's Corn Special	.....	.....	1.28	1.85	1.84	1.66	.....	.....	8.74	8.42	8.18	8.	.....	.....	5.16	5.99	5.02	5.
Armour's General Farm	.....	.....	.....	0.76	1.34	0.89	.....	.....	.....	8.98	8.78	8.	.....	.....	.....	3.20	3.50	3.
Armour's High Gd. Potato.	.....	.....	1.86	1.77	1.95	1.66	.....	.....	9.84	8.14	8.68	8.	.....	.....	10.35	9.80	9.79	10.
Armour's Oats and Clover	.....	.....	.....	.....	.....	.....	.....	.....	11.80	9.82	10.16	10.	.....	.....	8.88	8.08	7.89	8.
Bowker's Corn Phosphate	2.00	1.61	1.79	2.12	1.77	1.66	8.60	8.54	8.10	9.20	8.56	8.	2.32	2.15	2.29	2.14	2.16	8.
Bowker's Early Potato	3.51	3.58	.....	3.56	3.44	3.99	5.68	8.28	.....	8.36	8.66	8.	7.42	6.70	6.89	6.89	7.56	7.
Bowker's Hill and Drill	2.60	2.86	2.74	2.79	2.69	2.47	9.26	9.44	9.90	9.24	10.14	9.	2.17	2.68	2.04	2.61	2.32	8.
Bowker's Market Garden	2.60	2.77	2.49	2.67	2.58	2.47	6.48	6.66	5.74	8.12	6.90	6.	10.04	9.85	11.19	9.81	9.96	10.
Bowker's Potash Bone	1.12	1.12	1.14	1.46	1.00	0.89	8.10	8.76	9.08	8.70	7.94	6	2.12	1.93	2.26	2.20	2.22	8.
Bowker's Potash or Staple	1.19	1.30	1.25	1.35	1.04	0.83	7.62	8.98	9.20	9.18	8.64	8.	3.24	3.58	4.80	3.38	3.37	8.
Bowker's Pot. and Veg. F.	2.81	2.32	2.67	2.81	2.62	2.47	9.44	8.42	9.22	8.96	9.40	8.	4.72	4.57	3.84	5.10	5.52	4.
Bowker's Pot. and Veg. P.	1.89	1.65	1.78	2.19	2.02	1.66	8.82	8.70	8.03	9.20	8.94	8.	2.31	2.19	2.24	2.34	2.07	8.
Bowker's Sol. Pot. Phos.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.46	10.	.....	.....	.....	.....	7.01	8.
Bowker's Square Brand	1.96	2.09	1.98	1.97	1.62	1.66	6.72	8.22	7.85	9.56	7.28	6.	2.64	2.33	1.96	2.28	2.04	8.
Bowker's Stkbg. Corn M.	3.51	3.55	3.68	3.53	3.43	3.99	9.02	8.28	8.75	10.33	10.16	10.	7.60	7.01	7.04	7.85	7.28	7.

*Potash in brands thus marked is largely if not entirely sulphate †Contained 0.20 percent or more of mineral nitrogen.

ANALYSES OF LICENSED FERTILIZERS—1907-1911

BRAND	NITROGEN					AVAILABLE PHOSPHORIC ACID					POTASH							
	1907	1908	1909	1910	1911	Guar.	1907	1908	1909	1910	1911	Guar.	1907	1908	1909	1910	1911	Guar.
Bowker's Stkbgd. Pot. M.	† 3.33	3.24	3.40	3.44	3.39	3.29	6.60	6.14	6.90	6.96	7.16	6.	10.10	10.27	9.98	10.08	10.77	10.
Bowker's Stkbgd. Sd. Down	†	†	†	†	2.69	2.47	.....	.....	.....	.....	7.02	6.	.....	.....	.....	.....	10.55	10.
Bowker's Stkbgd. Top Dr.	6.03	4.91	4.77	5.21	5.11	4.93	6.06	4.44	7.77	5.32	4.70	4.	6.51	7.85	6.60	6.05	6.06	6.
Bowker's Super with P'tish	.....	.....	.....	.....	.....	.....	11.40	9.93	11.34	11.68	10.50	10.	2.52	1.50	1.80	2.32	2.82	2.
Bowker's Sure Crop Phos..	1.09	1.16	1.08	1.40	1.05	0.82	8.23	9.06	8.44	9.96	8.96	8.	1.95	2.02	2.37	2.18	2.17	2.
Bowker's Vt. Grange Ch..	.....	2.17	2.32	2.18	2.44	2.06	.....	8.02	8.30	9.88	9.12	8.	.....	3.05	3.24	3.52	3.05	3.
Bromley's Banner Brand..	.....	.....	.....	3.78	3.51	3.29	.....	.....	.....	8.00	8.76	8.	.....	.....	.....	9.84	9.09	9.
Bromley's Corn and Potato	.....	.....	.....	1.35	1.56	1.23	.....	.....	.....	9.84	8.78	8.5	.....	.....	.....	2.90	2.96	2.5
Bromley's Grass & Grain..	.....	.....	.....	†	.....	.....	.....	.....	.....	9.94	10.40	10.	.....	.....	.....	2.07	2.46	2.
Bromley's Gr. Mt. Brand..	.....	.....	.....	1.37	1.74	1.23	.....	.....	.....	8.88	7.48	8.	.....	.....	.....	5.23	5.59	5.
Bromley's Potato Special..	.....	.....	.....	2.05	1.72	1.65	.....	.....	.....	8.26	8.36	8.	.....	.....	.....	10.35	9.84	10.
Bromley's Spec. Corn Fert	.....	.....	.....	0.93	1.14	0.82	.....	.....	.....	7.84	8.24	7.5	.....	.....	.....	3.04	3.28	3.
Bromley's Spec. Pot. Fert.	.....	.....	.....	0.95	1.18	0.82	.....	.....	.....	8.29	8.12	7.5	.....	.....	.....	3.40	3.27	3.
Buff. F. Co. Celery & Pot..	† 1.68	1.65	1.93	2.05	1.64	.....	.....	7.71	8.08	8.14	8.94	8.	.....	10.45	10.64	10.86	9.81	10.
Buff. F. Co. Ex. Phos. & Pot.	.....	.....	.....	.....	.....	.....	.....	.....	10.78	10.26	10.38	10.	.....	.....	6.95	8.04	8.04	8.
Buff. F. Co. Farm. Choice..	0.98	1.09	1.19	1.25	1.11	0.82	6.28	8.48	9.88	8.46	8.44	8.	4.14	5.02	4.72	4.93	4.93	5.

*Potash in brands thus marked is largely if not entirely sulphate. †Contained 0.20 percent or more of mineral nitrogen.

ANALYSES OF LICENSED FERTILIZERS—1907-1911

BRAND	NITROGEN					AVAILABLE PHOSPHO'IC ACID					POTASH				
	1907	1908	1909	1910	1911	1907	1908	1909	1910	1911	1907	1908	1909	1910	1911
	Guar	Guar	Guar	Guar	Guar	Guar	Guar	Guar	Guar	Guar	Guar	Guar	Guar	Guar	Guar
Buff. F. Co. Fish Guano....	1.43	1.26	1.12	1.09	0.89	6.76	9.28	9.69	9.26	.....	3.14	3.25	1.89	2.02	.....
Buff. F. Co. General Crop..	.....	.....	.....	.....	.....	9.20	10.77	9.62	8.72	8.69	3.65	5.15	3.02	3.34	3.36
Buff. F. Co. High Gr'd Man	.....	.....	.....	3.51	3.18	.....	.....	.....	7.58	8.12	.....	.....	.....	9.58	10.08
Buff. F. Co. New Eng. Spec.	1.51	1.93	1.75	2.00	1.91	7.60	8.52	9.60	9.69	9.84	5.06	4.59	6.01	4.90	5.51
Burl. R. Co. Animal Brand	2.80	2.95	2.81	2.55	2.48	6.44	5.32	4.41	5.80	5.30	4.10	4.50	4.13	4.58	5.19
Burl. R. Co. Spec. Potato..	2.91	2.96	2.67	2.77	2.58	6.76	5.06	3.65	4.14	7.02	5.42	7.34	6.62	6.96	6.52
Coe-Mort. Ext. Spec. Pot...	.....	.....	.....	1.53	1.79	.....	.....	.....	7.96	7.97	.....	.....	.....	10.48	9.38
Coe-Mort. Col. Corn & Pot.	.....	1.26	1.26	1.49	1.50	.....	8.06	8.96	9.24	8.40	.....	2.43	2.56	3.40	2.67
Coe-Mort. Gold Brand.....	2.00	2.42	2.76	2.50	2.58	5.52	8.05	8.33	8.06	7.92	9.40	5.67	5.69	6.76	5.89
Coe-Mort. H. G. A. B. Super	.....	2.03	2.17	1.93	2.09	.....	9.74	10.10	8.36	8.10	.....	2.84	3.22	3.30	3.54
Coe-Mort. N.E. Corn & Pot	0.93	1.19	1.15	1.21	1.10	5.72	8.84	8.45	7.96	8.24	3.26	2.84	2.74	3.08	2.95
Coe-Mort Prize Gr. & Gr...	.....	.....	.....	.....	.....	.....	11.18	12.18	9.78	10.00	.....	1.64	1.49	2.02	2.06
Coe-Mort Sp. Pot. & Fruit	.....	.....	.....	.....	1.98	.....	.....	.....	.....	6.06	.....	.....	.....	.....	4.06
Coe-Mort. Stand. Potato ...	.....	.....	.....	.....	3.25	.....	.....	.....	.....	6.06	.....	.....	.....	.....	10.22
Essex A 1 Superphos.....	.....	1.14	1.70	1.40	1.37	.....	8.42	7.68	7.28	7.50	.....	2.13	2.76	2.56	2.25
Essex Comp. Corn, etc.....	.....	3.13	3.13	3.27	3.63	.....	6.10	6.08	6.19	6.90	.....	10.44	11.91	10.70	9.62

*Potash in brands thus marked is largely if not entirely sulphate. †Contained 0.20 percent or more of mineral nitrogen.

ANALYSES OF LICENSED FERTILIZERS—1907-1911

BRAND	NITROGEN					AVAILABLE PHOSPHO'IC ACID					POTASH							
	1907	1908	1909	1910	1911	Guar	1907	1908	1909	1910	1911	Guar	1907	1908	1909	1910	1911	Guar
Essex Comp. Potatoes, etc...	.....	3.44	3.30	3.29	3.56	3.28	.....	5.58	6.70	7.01	7.40	6.	.....	10.80	10.17	10.10	10.14	10.
Essex Grain and Grass.....	.....	1.02	1.13	1.14	0.97	0.82	.....	9.08	8.27	8.60	8.68	8.	.....	4.46	4.51	3.94	4.10	4.
Essex Mar. Garden & Pot...	.....	1.98	1.95	2.42	2.13	2.	.....	7.93	8.08	8.11	8.54	8.	.....	5.55	5.48	5.47	5.14	5.
Essex XXX Fish & Pot....	.....	2.10	2.21	2.32	2.43	2.	.....	9.14	8.30	8.43	8.56	8.	.....	3.04	3.16	3.20	3.36	3.
Lister's G. Brand.....	0.88	0.98	1.12	1.26	1.00	0.82	8.64	8.16	8.10	8.74	8.56	8.	4.03	3.94	4.17	4.68	4.01	4.
Lister's Grass & Grain Fert	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.24	10.52	10.	.....	.....	.....	2.21	2.22	2.
Lister's Grass and Oats.....	.....	0.95	1.05	1.30	.....	0.82	.....	8.05	8.27	8.38	.....	8.	.....	3.70	4.90	4.33	.....	4.
Lister's Oneida Special.....	0.98	0.98	1.04	1.21	1.09	0.83	7.70	7.34	7.82	7.66	7.44	7.	1.17	1.33	1.50	1.57	1.07	1.
Lister's Potato Manure.....	3.68	3.61	3.79	3.64	3.46	3.29	9.24	8.75	8.46	8.28	8.36	8.	7.00	7.26	7.44	6.43	7.90	7.
Lister's Special Corn Fert...	1.82	1.79	1.89	1.51	1.47	1.23	8.42	8.55	8.10	8.40	8.70	8.	3.30	3.49	3.30	3.48	3.36	3.
Lister's Special Pot. Fert...	1.79	1.89	1.88	2.23	1.97	1.65	8.12	9.07	7.75	8.10	8.22	8.	3.18	3.35	3.78	3.51	3.34	3.
Lister's Special 10% Potash	1.72	1.79	1.91	2.00	2.05	1.65	8.46	9.80	8.61	7.92	8.44	8.	7.97	10.41	10.93	11.02	10.08	10.
Lister's Success Fertilizer...	1.40	1.30	1.44	1.37	1.56	1.23	9.08	9.42	9.58	9.40	9.60	9.	2.50	2.24	2.14	2.55	2.28	2.
Lowell (Swift's) Animal...	2.42	2.46	2.74	2.56	2.60	2.47	8.28	8.32	8.62	8.14	8.50	8.	4.35	4.15	4.42	4.14	4.03	4.
Lowell (Swift's) Bone Ft...	2.00	1.72	1.51	1.95	1.63	1.64	7.77	8.44	8.18	8.94	8.56	8.	3.24	3.26	3.38	3.13	2.78	3.
Lowell (Swift's) Cereal.....	1.16	1.02	1.00	0.90	1.19	0.83	7.84	7.32	7.61	7.26	7.94	7.	1.64	1.57	1.44	1.30	1.09	1.

*Potash in brands thus marked is largely if not entirely sulphate. †Contained 0.20 percent or more of mineral nitrogen.

ANALYSES OF LICENSED FERTILIZERS—1907-1911

BRAND	NITROGEN					AVAILABLE PHOSPHORIC ACID					POTASH					
	1907	1908	1909	1910	1911	1907	1908	1909	1910	1911	1907	1908	1909	1910	1911	
Lowell (Swift's) Empress..	1.30	1.37	1.47	1.37	1.43	1.23	7.54	7.34	7.84	7.52	7.68	2.01	2.23	2.19	2.47	1.78
Lowell (Swift's) Pot. Man	1.79	1.74	1.89	1.81	1.84	1.64	7.38	7.78	7.48	6.86	7.16	3.02	4.08	4.12	4.06	4.24
Lowell (Swift's) Pot. Phos	2.24	2.70	2.50	2.49	2.58	2.46	8.79	7.66	8.26	8.48	8.60	5.30	5.67	6.75	6.53	6.01
Lowell (Swift's) Spec. Corn	.....	.....	.....	.....	3.43	3.28	.....	.....	.....	.....	8.56	.....	.....	.....	.....	7.42
Lowell (Swift's) Spec. Pot	.....	.....	.....	2.64	2.65	2.46	.....	.....	.....	6.64	7.02	.....	.....	.....	10.44	10.42
Lowell (Swift's) Sterling	0.84	1.02	1.12	1.12	1.09	0.82	7.84	8.21	8.44	9.14	8.20	4.28	4.06	4.10	4.10	4.03
Lowell Swift's Superior.....	3.79	3.86	3.89	4.03	3.79	3.7	7.40	7.60	7.38	7.30	7.52	9.75	9.78	9.93	10.04	9.90
N. E. Complete Manure.....	.....	.....	.....	3.86	3.44	3.28	.....	.....	.....	6.52	6.46	.....	.....	.....	9.83	10.26
N. E. F. Co., Corn & Grain	1.40	1.23	1.55	1.58	1.47	1.23	7.52	7.06	7.48	7.66	7.74	1.88	2.06	2.57	2.20	2.02
N. E. F. Co., Corn Phos...	1.82	1.84	1.74	1.88	1.93	1.64	7.76	8.00	8.68	8.62	8.48	3.00	3.22	3.18	3.40	3.38
N. E. F. Co. Peerless.....	.....	0.98	0.98	1.00	0.86	0.82	.....	6.89	8.00	7.34	7.46	.....	1.23	1.14	1.22	1.11
N. E. F. Co. Potato Fert...	1.75	1.89	1.86	1.88	1.70	1.64	7.28	7.12	6.99	7.46	7.30	3.47	4.06	4.27	3.83	4.06
N. E. F. Co. Superphos.....	.....	.....	.....	.....	2.67	2.46	.....	.....	.....	.....	8.52	....	.....	.....	.....	4.26
P. & P. Co.'s Corn & Gr. Ft	.....	.....	.....	1.09	1.09	0.82	.....	.....	.....	8.40	8.98	.....	.....	.....	3.96	4.13
P. & P. Co.'s Grain Grower	1.33	1.47	1.49	1.42	1.33	1.23	6.66	7.32	6.95	7.50	7.08	1.92	2.36	2.10	2.36	2.13
P. P. Co.'s Plym'h Rock...	2.62	2.49	2.67	2.44	2.65	2.47	7.75	8.20	7.62	7.80	9.18	3.86	4.32	4.50	4.26	4.01

*Potash in brands thus marked is largely if not entirely sulphate. †Contained 0.20 percent or more of mineral nitrogen.

ANALYSES OF LICENSED FERTILIZERS—1907-1911

BRAND	NITROGEN				AVAILABLE PHOSPHORIC ACID				POTASH			
	1907	1908	1909	1910	1911	Guar.	1907	1908	1909	1910	1911	Guar.
P. & P. Co.'s Potato Fert...	1.86	1.89	2.83	1.91	1.77	1.65	6.30	6.04	7.19	6.64	6.72	6.
P. & P. Co.'s Pot. Grower...	.....	2.49	2.57	2.81	2.66	2.46	.....	6.26	6.42	6.32	6.38	6.
P. & P. Co.'s Star Brand...	1.65	2.24	1.70	2.07	1.92	1.65	7.28	7.16	6.85	7.60	7.45	7.
R. & H. Co.'s Compl. Phos	1.16	1.12	1.54	1.63	1.83	1.5	8.04	8.42	7.72	8.50	8.10	7.
R. & H. Co.'s Grass & Gr...	3.33	3.05	3.30	2.59	2.37	2.2	6.03	7.12	8.06	10.24	9.75	6.5
R. & H. Co.'s New Mkt. Gd.	.....	.....	1.61	2.05	2.44	2.	.....	.....	6.16	7.45	6.86	6.
R. & H. Co.'s Oats & Top Dr.	8.21	8.70	8.95	8.23	8.51	8.5	4.25	4.83	4.36	6.42	4.82	4.5
R. & H. Co.'s Potato Phos.	2.35	2.24	2.03	2.17	2.14	2.	9.82	8.82	10.34	9.80	9.86	9.
R. & H. Co.'s Sol. Co. G'l Op	2.35	2.35	2.74	2.88	2.89	2.5	7.84	6.40	7.12	7.79	7.14	6.
R. & H. Co.'s Sol. Potato...	4.53	4.95	5.42	5.30	5.14	5.	7.95	8.48	7.68	7.30	8.14	7.
R. & H. Co.'s Sol. Tobacco	5.30	4.55	4.91	5.07	5.19	5.	9.82	8.04	6.18	7.62	7.20	7.
Sanderson's Atlantic Coast	.....	.....	.....	2.63	2.21	1.67	.....	.....	.....	5.28	5.34	4.
Sanderson's Corn Superph.	.....	.....	.....	2.41	2.28	1.67	.....	.....	.....	7.30	8.70	7.
Sanderson's Formula A....	.....	.....	.....	3.56	3.35	3.33	.....	.....	.....	7.54	7.24	6.
Sanderson's Potato Manure	.....	.....	.....	1.84	2.28	1.67	.....	.....	.....	6.46	6.68	5.
Sanderson's Special 10 %...	.....	.....	.....	2.67	3.33	2.47	.....	.....	.....	5.84	7.12	5.

*Potash in brands thus marked is largely if not entirely sulphate. †Contained 0.20 percent or more of mineral nitrogen.

(f) Nitrogen guaranty, 1 percent; available phosphoric acid guaranty, 8 percent; potash guaranty, 3.5 percent. (g) Available phosphoric acid guaranty, 3.9 percent.

VII. LIMES AND LIMING

It is a settled policy at this Station yearly to "feature" some special topic in its main annual fertilizer bulletin. The law provides for the publication of "information in relation to the character, composition, value and use" of fertilizers. A somewhat complete survey of matters in close "relation to" the purchase and use of fertilizers has been made in recent years. Analyses have been printed, comparisons with guaranties instituted, and the relationship of selling prices and money values of the plant food contents discussed; valuations, guaranties and their meaning, brand names and their lack of meaning, the nature, sources and functions of the deficient elements of plant food have been considered; the several brands have been classified; the character, composition, application and use of farm manures have been reviewed; the systems and methods which prevail in the use of plant food have been outlined, and suggestions offered as to amounts and kinds for sundry Vermont soils and crops. All this has been done in the hope that such a survey might aid in placing Vermont farm practice upon a higher plane and a more rational basis. While it is necessary yearly to make and to print analyses and to comment thereon, and advisable annually to discuss the financial phase of the proposition, the special features of bulletins 99, 108 and 116 (1903 to 1905) do not need repetition, at present at any rate, since these bulletins have been widely distributed and are still available on demand.¹

The more obvious and immediate matter "in relation to" fertilization having been covered, it seemed fitting in 1906 to begin to review matters less closely connected therewith; to pass from the consideration of artificial means of soil betterment to that of natural ones. Consequently the moisture relations of the soil, particularly as regards water control, through irrigation, drainage and adequate tillage operations, were discussed at length

¹ Bulletin 116 is largely called for but is available as a loan only, the edition being nearly exhausted. Circular 7 contains certain and the more important portions of this bulletin and is available.

in the 1906 bulletin, No. 123. And, in pursuit of the determination expressed therein, to discuss "sundry phases of soil management during the next few years," a review was made in 1907 of soil biology as it relates to fertilization and particularly to the soil nitrogen content; in 1908 of the causes and remedies of soil deterioration; of the methods of renovation; and of the ways by which further soil treatment may improve rather than impoverish, all with special reference to the humus content of the soil and its maintenance; in 1909 soil physiography was discussed, the fundamentals of soil making, the ways in which during the ages soil has been formed from rock and organic matter; and in 1910 the classification of soils and, incidentally, their adaptations were discussed. The writer hopes by the annual issuance of these fragments, to furnish within a few years a fairly complete presentation of the general subject. He plans in the near future to print in this series articles dealing with soil chemistry and soil physics, but is not ready at present to place himself on paper as regards either phase of this subject. Then, moreover, it now seems an opportune time to issue a new statement as to the practice of liming, because of the large call for information touching this phase of fertilization. Hence, breaking the series of bulletins dealing specifically with natural means of soil betterment begun in 1906 and reverting to that which dealt with artificial ones issued from 1902 to 1905, the present article is offered.

Bulletin 99, printed eight years ago, contained among other things, a seven page article on limes and liming. This is the only statement as to this matter issued by this Station. This bulletin has done valiant service. It has conveyed information touching this matter to thousands of inquirers, and now but few copies are left. Furthermore, during the last decade our views touching this phase of fertilization have become in some degree modified; and, finally, the 1903 presentation did not pretend to be a complete one. These considerations, as well as the large call for information as to the practice of liming, seem to make it

desirable to reshape and to enlarge upon the former article for the special feature of this year's fertilizer bulletin.

Commercial fertilizers are not guaranteed to contain lime, yet as a matter of fact they all do contain it. The average commercial fertilizer as sold in Vermont, carrying about 2 percent nitrogen, $8\frac{1}{2}$ percent phosphoric acid, and nearly 5 percent potash, necessarily contains in the vicinity of 12 to 15 percent of lime, combined partly with the phosphoric acid, and partly with the sulphuric acid used in making the phosphate rock available. This lime does not exist in the same form that it does in quick lime or in the original limestone rock. It is combined with acids, yet it is serviceable for many of the purposes for which farmers apply lime to soil. As yet the fertilizer law does not recognize its presence in the commercial fertilizer. It is not accorded a commercial value by the trade, which buys it incidentally as it were without paying for it, since the rock or bone which contain it are bought for their content of phosphoric acid and not for that of lime. Limes are as yet included within the purview of the fertilizer laws of but few states. It is plain, however, that in the not distant future, as liming becomes a more common practice in Vermont, there will arise a necessity for some degree of control of the sale of this commodity, including the statement by its manufacturers of its composition. For there are limes and limes. The action of the same lime on different soils is divergent and the action of different limes on the same soil varies. A sandy soil and a clay loam are diversely affected, and a straight lime and a magnesian lime afford unlike results.

EARLY USAGE

The use of lime in fertilization dates back to antiquity. Of course our Roman forbears did not know the mode of its action, but they appreciated its value. For instance, marl, which is now again on the surface of public approval after a long submergence, was used by the ancient Romans. Cato, who died 150 years B. C., is said to have described a limekiln. Wood ashes

were used in horticulture. To what extent liming was practised when Rome ruled the world is not known, or what was its vogue during the middle ages; but there seems reason to believe that it was not a common custom before the seventeenth century.

The practice of liming was probably brought to this country by the earlier settlers. It is described in American agricultural literature of the eighteenth century. Prior to the introduction of commercial fertilizers soon after the middle of the last century, gypsum or land plaster, marl, wood ashes and burned lime, were largely used by eastern farmers, particularly in Canada, New York and Pennsylvania. The good results obtained with commercial fertilizers and the ease of their purchase led farmers to discontinue the use of lime; and the small farm limekiln, common in lime using regions, was left unlighted. Fifteen years ago liming was almost an unknown practice in New England; it was uncommon in New York; practice somewhat in northern and central New Jersey, considerably in central Pennsylvania, to a limited extent in Maryland and West Virginia, and rarely in Ohio. Now, however, the pendulum is swinging back. The use of agricultural lime is rapidly increasing, mainly because of the more exact understanding now extant as to the nature of the service which it renders, as well as of the dangers attending its unintelligent use.

Roberts¹ stated in 1897 that 99 percent of the arable land in this country had never been limed and ventured the prediction that it never would be because of its inaccessibility to the sources of the raw material and the fact that, in his estimation, the soil did not need lime. It is fairly safe to say today, however, that this prediction is not justified, since later investigation has indicated a much more universal need of lime than was at that time understood, a need the realization of which is leading to its rapidly increasing use.

¹ *The Fertility of the Land*, p. 305 (1897).

VERMONT'S PRODUCTION

Vermont averages to make about \$200,000 worth of lime annually; but its production is highly irregular. In 1893 \$400,000 worth is reported; a year or two later only \$150,000 worth. The latest data at hand—1908—states the output at 32,691 tons, valued at \$170,205 or \$5.21 per ton, this being made by ten manufacturers. Vermont ranks well in the production of lime, being outclassed in the North Atlantic states only by Maine, New York and, possibly, Massachusetts. The lime product of the entire country exceeds \$11,000,000 annually.

WHAT IS LIME?

The term is somewhat loosely applied to several compounds which contain the metal calcium. Thus the common compound of this metal with the gaseous element oxygen, known as quicklime; its compound with the elements of water—hydrogen and oxygen—known as slaked lime; its compound with the elements of water and the carbonic acid of the air, known as air slaked lime; all these are spoken of in every day parlance as lime. Strictly speaking, however, the term should be applied only to the first named material, calcium oxid or quicklime. None of these products, the metal calcium, the oxid or quicklime, or the more or less impure slaked limes, occur free in nature. The metal would oxidize or tarnish promptly and change to quicklime, the latter would air slake, and the two slaked limes in the course of time would change by exposure to the air becoming carbonated. (In this connection, see classification, page 408).

FORMS OF LIME

Lime is found in nature in several combinations and it occurs in the trades in several artificial forms. The natural forms are listed below and on the next page as follows:

1. *Carbonate*, a combination of lime with carbonic acid (carbon dioxid), found in nature as limestone, marble, marl, oyster and clam shells, chalk, coral, etc. Pages 392-399.

2. *Sulphate*, a combination of lime with sulphuric acid and water; found in nature as gypsum or land plaster. Pages 399-400.

3. *Phosphate*, a combination of lime with phosphoric acid; found in nature in phosphate rocks of various kinds. Page 400.

Among the artificial forms of lime may be mentioned:

1. *Oxid*, that is to say, burned lime, quicklime, a product of the limekiln; a combination of lime with oxygen. Pages 400-402.

2. *Hydrate*, that is to say, slaked lime, the chemical union of water with lime. Pages 402-404.

3. *Impure hydrate* mixed with carbonate, in the form of air slaked lime, that is to say, a quick or burned lime which has become slaked by exposure to damp air, gathering both carbonic acid and water therefrom. Page 404.

4. *Impure carbonate* in the form of leached or unleached wood ashes, limekiln ashes, cottonseed hull ashes, etc.; the lime being freed by combustion from the organic matter, the carbonate being formed by its combination with the carbonic acid derived from the combustion of the organic matter. Pages 404-405.

5. *Phosphate*, carrying varying proportions of lime and formed by the action of sulphuric acid used in the manufacture of acid phosphate from phosphate rock or other phosphatic material; also basic slag, a Bessemer steel product. Pages 405-406.

6. *Sulphate*, as gypsum produced in the manufacture of superphosphate; a combination of lime with sulphuric acid.

CARBONATES

A *limestone* chemically is a calcium carbonate. Its impurities usually consist of silica, iron and alumina, sulphur, alkalis, etc. Another common constituent is carbonate of magnesia, which replaces more or less of the calcium carbonate. It may exist simply as an impurity or it may be the dominant constituent. A highly magnesian limestone is termed a "dolomitic"

limestone. The silica exists as sand grains or as silicate of alumina, the iron as pyrites or in other forms, the sulphur as pyrites or gypsum.

Vermont limestone is commonly a fairly pure carbonate of lime (calcite) containing more or less—usually less—carbonate of magnesia (magnesite). It is of somewhat uneven composition, even in one location, yet there seems reason to believe that it is rarely sufficiently magnesian in character as used and burned in Vermont to make it inapplicable to agricultural uses. Indeed in most cases as compared with the limestones in many other sections it appears to be a relatively pure calcium rock.

Limestones occur in every state in the country; in some in sparse amounts, in some underlying almost the entire area. They usually originate from deep sea deposits, formed from the calcareous remains of sea organisms (foraminifera, corals, molluscs), which have been upheaved above the sea level in relatively late geological times.

Concerning the Vermont deposits the State Geologist says in his last report, as well as in that of 1899-1900, from which piecemeal the following statements are drawn, that:

"Limestone does not occur in such extensive areas nor in such thick beds as it does in some states, but there are scattered over the State ledges of limestone, some of no inconsiderable size, from which much limestone has been obtained. * * * * *. Nearly all are located in the western part and not far from Lake Champlain. * * * * *. East of the Green mountains lime has been burned at Whitingham, Plymouth, Townshend, Weathersfield, Cavendish and other places. West of the mountains it has been obtained at Highgate, Swanton, Colchester, Grand Isle, Brandon, Leicester Junction and elsewhere and, of course, throughout the marble border."

Vermont furnishes annually about \$20,000 worth of limestone as such, used largely for constructional purposes, for road making and in the making of concrete. The amount thus far

used for fertilizing purposes in the form of ground limestone is, apparently, too small to figure statistically.

The list of quarries now being worked is as follows:

Addison county—New Haven (P. O. Middlebury), Green Mountain Lime Co.; Leicester Junction, Brandon Lime and Marble Co.; Leicester Junction, Leicester Marble & Lime Co.

Bennington county—Readsboro (P. O. Greenfield, Mass.), Vermont Lime Co., Inc.

Chittenden county—Colchester (P. O. Burlington), G. B. Catlin.

Franklin county—Highgate, L. E. Felton; St. Albans, W. B. Fonda; Swanton, Swanton Lime Works.

Grand Isle county—Isle La Motte, N. B. Fiske (building limestone and road material only).

Windsor county—Weathersfield (P. O. Amsden), Amsden Lime Works. (Building limes only).

To be properly fitted for agricultural uses a limestone should be ground fine enough to pass an 80 mesh sieve, and if it is yet finer, it is the better for it. Some authorities are not insistent on this point, claiming that extreme fineness is not necessary; but most investigators of this matter hold to the contrary. Obviously, however, even distribution is promoted by fineness of grinding. Little, if any, machinery is as yet in operation in Vermont for the grinding of limestone and probably none is used in grinding it for agricultural uses. That such will be installed when the demand for this product arises may be considered as certain, but the value of ground limestone as a soil amendment is now appreciated by but few Vermont farmers. Small mills are on the market wherewith it is claimed limestone may be ground in a small way on the farm. A high grade limestone dust, both fine and pure, is offered just beyond the southern Vermont border by the New England Lime Co. at North Adams, Mass. Massachusetts station analyses show it to carry from 60 to 70 percent calcium oxid and to be a carbonate mixed with slaked lime. It is stated to be the fine particles of stone which

are drawn out of the kiln by its draught and deposited in the dust chamber at its back.

Marble differs from limestone physically rather than chemically, being relatively hard in structure and close in texture. For obvious reasons it rarely enters into agriculture, either as marble dust or as raw material for lime making. It would appear on theoretical considerations, moreover, that on account of its harder character it would not be so successful a soil amendment as would limestone dust. One would not expect it to disintegrate as readily.

Marl. There are marls and marls; clay marls, sand marls, shell marls, greensand marls, etc., variously termed according to their dominant ingredients. Such as are used in agricultural operations, however, are either calcareous (limy) in character or are potash containing (greensand or glauconite). The former are found more or less widely all over Vermont; the latter are certainly uncommon and probably do not occur. With the former only are we concerned in this article and they will hereafter be termed marls without qualifying adjective.

Chemically marl is a calcareous shell product of chemical and biochemical action; but its essential constituent—carbonate of lime—may be almost pure or be highly diluted with the sand and clay with which it has become admixed in deposition. Furthermore, since plant life functions in its deposition, its debris often contaminates the marl. In a series of 32 analyses of Wisconsin¹ marls carrying from 86 to 97 percent carbonate of lime, the percentages of sand and silicates (largely clay), and of organic matter ranged from 0.50 to 9 percent and from 0.10 to 8 percent respectively. Marls usually carry a modicum of nitrogen, doubtless slowly available, some alumina and iron oxid, more or less magnesia, etc. Many of them when dug are quite wet, carrying perhaps 15 to 25 percent, and indeed 50 percent or more if dug from swamps.

Physically a marl is a fine grained, loose, friable material,

¹ Wisconsin Sta. Bul. 56 (1897).

often sticky or putty-like in its consistency when dug, a condition due to its moisture content. Its color ranges from white to gray. Its texture is highly variable. It often happens that marl in its crude condition contains considerable amounts of material which do not pass the 20 mesh sieve. It is relatively light in weight.

Marls occur north of, but rarely south of, the line of glaciation and hence are inevitably of relatively recent geological origin. They are somewhat common in the Canadian provinces, in New England, New York, Michigan and in the great lake region. No very extensive deposits have been developed in New England; it is doubtful if many exist. Quite large areas are now being developed in Orleans county, however. Several of relatively small size occur in Vermont pond bottoms, in old lake beds, or under peat layers in muck swamps. Marls usually occur in small basin-like depressions which are or have been occupied by a pond. The deposits are in some cases forming, in others they are formed. In the one case the pond still exists; in the other the marl bed occurs in a swamp or marsh covered with peat or muck, or in a spot already dried out.

Ponds abound in such glaciated regions as New England. They are commonly caused by the damming of a stream flow in the valley by such glacial debris as sand or clay; or by the irregular deposition of this debris which has led to the formation of hollows in which water has accumulated; or by the gouging out of depressions in the softer rock by the passage of the glacial ice sheet. In all these cases the basins became water filled, the ponds were born and at once began to die. Their death is a slow process, however, being usually due to the filling up of the hollow by deposits of rock particles, entangled by organic growth, infiltrated often with carbonate of lime in solution and withdrawn therefrom by deposition. (See bulletin 154, pages 709-710 as to the formation of "cumulose soils").

The present views as to the causes of marl deposition are that there are at least three different methods whereby this end is accomplished :

1. The solution of limestone by natural rain-water carrying carbon dioxid (carbonic acid gas) and its more or less complete deposition when the water becomes warmer, when pressure lessens, or when the gas escapes.

2. The removal of the carbon dioxid from the water and the freeing of oxygen therefrom by stoneworts and other algae, the incrustation of the calcium carbonate thus thrown down on the vegetable matter, and the direct assimilation of the lime salts.

3. Through the action of molluscs.

A brief statement concerning each of these processes seems in order :

1. Rain-water washes more or less carbonic acid gas out of the air. Every drop when it strikes the earth is really an extremely dilute acid fluid. This dissolves limestone more readily than it does any other rock. Hence in limestone regions,—and such exist along the Appalachians from Vermont to Georgia, in the lake region, in New York, Ohio, Michigan, Wisconsin, and in Missouri,—the water in many streams is hard and all of them bear an invisible burden of lime carbonate. The pulverized, limy debris of glacial action, moreover, lends itself readily to solution.

The carbon dioxid contents as well as the warmth of the water affect its powers of solution. The greater the one and the less the other, within limits, the more limestone is dissolved. If the gas wholly or in part escapes because of lowering pressure, and if the solution grows warmer, the lime is deposited as carbonate. The "fur" on a teakettle is a familiar example of this action. When a cold brook or spring flows into a warm and quiet pond, a part of the lime salts it carries in solution settles out as a powder. The same thing happens when its carbon dioxid passes off into the air.

2. All green plants absorb carbon dioxide through their leaves, building the carbon together with some of the oxygen into their structure. The acquirement of the carbon dioxide which is taken from the water by the microscopically small aquatic plant life of a pond tends to precipitate the lime salts as an incrustation on the plant stems and leaves. Furthermore, the passage of oxygen from the leaf and the cleavage of the carbon dioxide, resulting, theoretically, in oxygen freeing, tends to re-form and to throw down calcium carbonate as a powder. And, finally, certain aquatics build lime into their tissues.

3. The presence of large quantities of shells in most marls is evidence of one way in which these deposits are formed. The withdrawal of lime from calcareous waters by these minute animals for the purpose of constructing their shells is a well understood phenomenon.

Several samples of Vermont marls have been submitted to analysis particularly of late years. Their analyses follow:

Sample sent from	Calcium oxid (lime)	Equivalent to carbonate of lime	Magnesium oxid (magnesia)	Equivalent to carbonate of magnesia	Iron and aluminum oxids	Sulphuric acid	Insoluble matter
Poultney,	47.96	....	0.86	....	....	....	1.68
West Burke,	45.69	....	....	....	....	....	5.03
West Burke,	23.22	....	....	....	....	....	42.09
Sutton,	51.60	....	0.40	....	0.85	....	1.69
Benson,	34.60	61.75	5.92	12.37	....	....	24.55
Newport,	48.46	86.48	1.52	3.18	1.12	0.82	0.40
McIndoes,	46.06	82.20	0.70	1.46	1.80	1.55	8.19
Brattleboro,	47.16	84.16	0.87	1.82	1.02	1.73	9.08
Brattleboro,	47.00	83.87	0.75	1.57	1.56	1.76	8.53
Brattleboro,	46.20	82.44	0.83	1.73	1.80	1.60	7.88
Windsor,	44.25	78.96	....	....	....	....	8.36

NOTE.—The blanks are not to be construed as indicative of lack of these constituents in the sample, but simply that the determinations were not made. In no case does the analysis purport to be a complete one.

Marls are used for many purposes other than as a soil amendment, as, for example, in the manufacture of Portland cement, of quicklime, and as a polishing and scouring powder.

Two concerns are offering marl in the state of Vermont today: Orleans county, Barton, H. F. Pillsbury & Son; Windham county, Brattleboro, Vermont Marl Co.

The effect of marl as a soil amendment should be fully as great as that of an equivalent amount of finely ground carbonate of lime secured from any well recognized source. If of fine texture, an impalpable powder, as most marls are after they are dried, it is relatively soluble in water, is ready for direct application and should give as good service as does any other carbonate, unless it be on soils where magnesia is needed, in which case a finely ground dolomitic limestone would be likely to prove more useful.

Oyster shells, coral, chalk and the like obviously cut no figure as purveyors of lime for agricultural uses in an inland state. They carry from 90 to 95 percent of carbonate of lime and furnish, when burned, a high grade of lime containing from 85 to 95 percent of quicklime.

SULPHATE

Sulphate of lime, gypsum or land plaster—is a widely disseminated material, usually deposited from ancient oceans or formed by limestone transformations. It is found in many sections, notably in Michigan, New York, from Kansas south to Texas, generally in the vicinity of the great lakes and at many points of the far west. Large deposits occur in Nova Scotia and New Brunswick, which have entered into the American trade for years. In 1903 the importations of gypsum aggregated 300,000 tons, about 10 percent of which was entered at New England ports. There are no developed gypsum deposits in New England, most of the material used here coming from the maritime provinces or from Onondaga county, New York.

Gypsum chemically is a combination of lime with sulphuric acid. Two parts of water also enter into its composition as a part of its structure and not simply by absorption. It is generally contaminated with more or less clay, magnesia and limestone. Average Nova Scotia gypsum contains about 34 percent of lime, that from New York about 30 percent. It is a soft rock readily soluble in water, easily mined and readily ground. It is a well known and largely used soil amendment which deserves yet larger usage. More than a million tons are annually mined in this country, seven-eighths of which are calcined for use as wall plaster or as plaster of paris. About 6 percent is ground for use as land plaster, costing on the average somewhat more than \$2 a ton. A considerable amount of gypsum is formed in the production of acid phosphate by the use of sulphuric acid on ground phosphate rock, which is quite as serviceable for all practical purposes, as is the natural product.

PHOSPHATE

Phosphate rock is mined in the states of South Carolina, Florida and Tennessee and in many foreign countries, basic slag is put upon the market, and bones are gathered and ground mainly because of their phosphoric acid contents; but the lime which they contain has value, even though it is accorded no commercial rating. Lime while combined with phosphoric acid has no power to sweeten acid soils or to do many of the things noted on pages 412-428; but it may help crop growth notwithstanding. However, such low grade phosphate rocks as are rich in carbonate of lime may serve to sweeten soils and flocculate clays. (pages 413, 419); and a considerable proportion of the lime present in basic slag exists in an alkaline form (page 406).

Concerning the natural forms it may be said:

OXID

Calcium oxid (caustic, quick or burned lime) is obtained by burning limestone rock at a red heat in a kiln, the carbonic acid gas being driven off by the heat. The material thus formed

is very caustic or alkaline, eagerly absorbs water from the air, slakes when moistened, and becomes intensely hot, a phenomenon caused by the intense chemical action exerted by the water on the lime. Quicklime is the most energetic form of this commodity, but it is not commonly used in this form on the land. Its avidity for water and its increase in bulk due to its absorption, militates against its shipment in packages other than tight barrels, or in lump form in bulk. When sown as a quicklime, the fine dust proves extremely irritating to both team and driver, unless special precautions are taken to obviate dusting, a procedure which is not always easily accomplished. It is capable of doing anything which any other form can do, other than the sulphate. Its composition may range all the way from that of an almost pure calcium oxid to one containing not more than 50 percent thereof, the residue consisting mainly of magnesium oxid (magnesia), if the limestone is of a dolomitic or magnesian character. Of course other impurities, such as iron oxid, insoluble matter, sand, clay, etc., if present, tend to lower its quality. Magnesian limestones burn much as do calcite limestones.

The amount of lime yielded by the burning of limestone varies. A bushel of lime may weigh as low as 60 or as high as 100 pounds. Its legal weight in some states is 70 pounds, in others 72 pounds, in others 80 pounds. A magnesian lime will sometimes weigh more than will a straight calcite lime. An oyster shell lime is apt to weigh somewhat less. Probably on the average when fresh from the kiln, a heaped bushel weighs not far from 75 pounds. The caustic lime furnished by a ton of high grade limestone weighs about 1,100 to 1,200 pounds. Much water is absorbed in slaking and a ton of slaked or hydrated lime contains only about three-fourths as much lime as does a ton of unslaked lime. A heaped bushel of the latter should so increase in volume as to make $1\frac{1}{2}$ bushels of either air or water slaked lime. One hundred pounds quicklime con-

tains as much lime as does 133 pounds of slaked lime, or nearly 180 pounds of carbonate.

The burning of limestone. When limestone is burned in a kiln, "stone lime," or "quicklime," or "burned lime," results. A strictly pure limestone contains 56 pounds in a hundred of lime and 44 pounds of carbonic acid. The latter passes off as a gas when the limestone is burned, leaving the lime as a residue weighing but little more than half the original weight. The kiln temperature ranges from 650-900° C. (1200-1650° F.) varying somewhat according to the nature of the limestone. The process vaporizes the water, raises the broken stone to a temperature at which its lime and its carbonic acid are, as it were, torn asunder, and drives off the latter into the air. Several types of kilns are in use, the intermittent—now rarely used—and the continuous vertical, either with mixed or with separate feed. The limestone and fuel are charged in alternate layers in the vertical mixed feed type, and, as the product is burned, the roasted lime is drawn from the bottom of the kiln while fresh charges of limestone and fuel are added at the top. This type of the kiln is the cheapest in original cost and operating expense and its product is good enough for all but fancy purposes. The cost of lime burning is a variable factor depending on the initial cost and on depreciation of the plant, including quarry, kiln, etc., and the cost of fuel and labor. Careful estimates place the cost of production at from \$1.29 to \$2.90 per ton or from 4.2 cents to 10.15 cents per bushel of 70 pounds.¹ The average cost is doubtless from \$1.75 to \$2.25 per ton or 6 to 8 cents per bushel.

HYDRATE

The air or water slaking of lime is a chemical process. It is the change of calcium oxid or quicklime into calcium hydrate or slaked lime. It is a chemical union of the elements of water—oxygen and hydrogen—with those of lime—calcium and oxygen—56 pounds of the latter uniting with 18 pounds

¹Eckel, "Cements, limes and plasters," p. 110 (1905).

of the former to form 74 pounds of dry hydrate, the water entirely disappearing and entering into the structure of the substance. To be sure some water over and above this amount is mechanically absorbed and does not enter into the structure of the new compound, but, viewed from a chemical standpoint, this is an incident and not a necessary feature of the process. The slaking of lime produces great chemical heat, a considerable expansion, and, if the operation is properly conducted, a fine powdery mass. If the limestone is magnesian in character it slakes less actively and its soil action seems to be less vigorous. Such are not usually rated as favorably as are the straight limes.

It is quite common in farming practice to slake quicklime by heaping three or four bushels in a small pile, covering it with a few inches of fresh, moist soil, from which the lime absorbs enough water to slake it; or, to cover large heaps of from 25 to 200 bushels with heavy layers of moistened soil, to make small openings with a crowbar into the interior of the mass and to pour water into the pile through these orifices, the steam thus forming proving sufficient to slake the entire mass; or, if the amount to be slaked is very large, to spread a quarter part, to sprinkle thereon from 2 to $2\frac{1}{2}$ pails of water per barrel, at once to place the residue thereon, to add more water in the same proportion and to cover the whole with moist earth. Piles should stand a few days before using in order that all the lumps may be fully slaked and crumble to a powder.

Slaked or hydrated lime as sold for agricultural purposes is apt to be less uniform in composition than is either limestone or quicklime. This is due mainly to the variable amount of water it contains over and above that which enters into its chemical structure. Then, again, lime which is not good enough for builders' purposes is usually classified as agricultural lime and sold as such. Again, it sometimes contains rock other than limestone, is imperfectly burned, or is off color. For these reasons two different lots of slaked lime may prove unequally effective. They serve as justification of the passage, in other

states where liming obtains more largely than it does in Vermont, of laws looking toward the regulation of the sale of this commodity. Both this and the succeeding form—air slaked lime—are active and capable of doing all that any form save sulphate can do.

IMPURE HYDRATE

Whenever lump lime is allowed to lie exposed to air it crumbles to a powder. This process is termed air slaking, and is brought about by the absorption of moisture and carbonic acid (carbon dioxid), the quicklime slowly changing from the oxid form to that of hydrate. The product is a mechanical admixture of unchanged quicklime—calcium oxid—of hydrated lime—calcium hydrate—and of carbonate of lime, formed by the action of the carbonic acid of the air. This process may take place in a few weeks, or it may be a year before it is completed; in fact complete slaking rarely occurs. The proportions of calcium oxid, hydrate and carbonate in an air slaked lime vary greatly, owing to the natural variations in the character of the original material and in the nature and length of the exposure. The product may range all the way from a partially slaked lime to one which has become thoroughly carbonated. Because of its carbonate content, air slaked lime is less acrid in its nature than is either the quick or the slaked limes.

IMPURE CARBONATE

There are several forms of ashes formed at farm or factory, such as leached and unleached wood ashes, cottonseed hull ashes, limekiln ashes and the like, which furnish lime, mainly as carbonate, to the fertilizer trade. These materials are rarely used in the manufacture of commercial fertilizers as such, but are commonly sold in their crude condition. They contain more or less potash, mainly as carbonate and silica, some phosphoric acid, usually in an insoluble condition, and are rich in lime as carbonate of lime. Ordinary unleached wood ashes, if made from hard woods, are apt to carry from 5 to 7 percent

of potash, from 1 to 2 percent of phosphoric acid, from 3 to 5 percent of magnesia, and from 30 to 40 percent of lime, or sometimes even more. If leached, their potash content is lessened, but on the same moisture basis that of the other constituents is not materially affected; if anything it is relatively slightly increased. Soft wood ashes are more apt to vary in composition than are those made from hard woods, sometimes running as low as 23 percent of lime, at others as high as 45 percent. The ordinary leached ashes are apt to carry about a third part of their weight of water, and in that condition to contain 30 percent or less of lime. Limekiln ashes, the admixture of the ashes from the fuel used in the kiln, together with the fine lime falling therein, naturally vary in composition, often carrying as high a lime content as 50 percent or more, and sometimes, particularly when coal is used, as low a content as 35 percent. The average is probably not far from 40 percent of lime. Their potash percentage is apt to be low. Cottonseed hull ashes are less common today than formerly and rarely enter into the Vermont trade. There are several lime wastes from such industries as dyeing, tanning, the manufacture of coal gas, of beet sugar, etc., which are often rich in lime but rarely, if ever, are found in Vermont. Because of the nature of its origin, lime derived from ashes is sometimes termed "vegetable lime." It is an active form, although somewhat less energetic than are the more acrid oxid and hydrate. It is in an available condition, but is usually relatively costly at market prices. Of late years Canada ashes have sold in Vermont from \$10 to \$12 per ton.

PHOSPHATE

Phosphate of lime, which is derived from phosphatic rock, from boneblack or from bone, when treated with a sufficient quantity of sulphuric acid, becomes to a certain extent soluble and furnishes more or less free phosphoric acid, mono-calcic (soluble) phosphate, di-calcic (reverted) phosphate, sulphate of lime or

gypsum, and, usually, some tri-calcic (insoluble) phosphate representing the original unaltered material. About a third of the lime in materials thus treated is left united with the phosphoric acid, while two-thirds of it joins with the sulphuric acid forming gypsum or land plaster, a material which is in no wise different from that which is mined and ground (page 399). The acid phosphate thus formed, because of its acidity, may not be as desirable a source of phosphoric acid or of lime for use on muck or peat soils as would be undissolved ground phosphate rock or ground bone. Indeed if, as is occasionally the case, there exists an excess of sulphuric acid in the acid phosphate, a temporary injury may be wrought to certain forms of soils, particularly those which may be relatively deficient in carbonate of lime. The lime in all these compounds, other than the tri-calcic phosphate, is completely soluble in water or in such solvents as are commonly found in the soil; hence all of it may be said to be in available forms. While never bought specially for its lime content, this is nevertheless a means of supplying lime for several of the purposes for which it is needed.

Basic slag (Thomas slag, slag phosphate) is a byproduct obtained in the manufacture of Bessamer steel by the basic process. It contains more lime—40 to 50 percent—than do most high grade phosphates, and both lime and phosphoric acid are readily available. Furthermore, free lime usually exists in basic slag as oxid and carbonate to the extent of from 2 to 8 percent. The slag possesses a distinctly alkaline reaction and some of its combined lime is readily liberated and capable, apparently, of acting as a base. This material, imported almost entirely from Germany, appears to be an effective means of furnishing both available phosphoric acid and available lime, particularly to upland soils naturally or artificially made acid, or to marsh or mucky soils, etc. It should be said, however, that it doubtless proves much less serviceable than does quick or slaked lime in bringing about clay flocculation (page 413), but that as

a follower in after years of an initial heavy application of one of the more acid forms it would be apt to prove very effective.

SULPHATE

Artificial gypsum or land plaster formed as is described under the last head, has the same effect in fertilization as is possessed by the natural material. See pages 399-400.

CLASSIFICATION OF LIMES

The following classification of limes was adopted two years ago at a conference of lime burners and of the experiment station directors of the New England states. While it has no legal or binding force it represents a sincere attempt in the direction of standardization and clearness of definition:

LIME	(1) High Calcium	(1) Hydrate	(1) Spraying	Must contain 93% combined oxides and hydrates and all pass a standard 100 mesh sieve.
			(2) Land	Must contain not less than 90% combined oxides, hydrates and carbonates of which not 25% shall be carbonates.
	(2) Dolomitic or High Magnesium	(2) Caustic	(1) Lump	Must contain 90% combined oxides and carbonates of which not more than 10% shall be carbonates, excepting Ground, which may contain 20% carbonates.
			(2) Fines	
			(3) Ground	
	(2) Dolomitic or High Magnesium	(3) Ground Limestone		Must contain 90% combined carbonates and pass 50 mesh sieve.
			(4) Kiln Slaked	Not guaranteed, contains core, ashes and refuse.

The following diagram shows the composition of the several forms of lime commonly used in fertilization. It should be noted that the diagram is based on averages and that dolomite and the lime burned therefrom and ashes of all sorts are highly variable in their composition:

CARBONATE OF LIME: LIMESTONE: SHELL MARL (if pure)

55% Lime

DOLOMITE: DOLOMITIC LIMESTONE

42% Lime	11% Mg.
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BURNT DOLOMITIC LIME

78% Lime	20% Mg.
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BURNT LIME: QUICK LIME

98% Lime

HYDRATED LIME: SLAKED LIME

73% Lime

GYPNUM: LAND PLASTER: SULPHATE OF LIME

33% Lime

AVERAGE WOOD ASHES

33% Lime	5% Potash
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AVERAGE LIMEKILN ASHES

42% Lime	2% Potash
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COTTONSEED HULL ASHES

7%	13%	23% Potash	9%
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Lime Mag-
 nesia

Phos-
phoric
Acid

BASIC SLAG

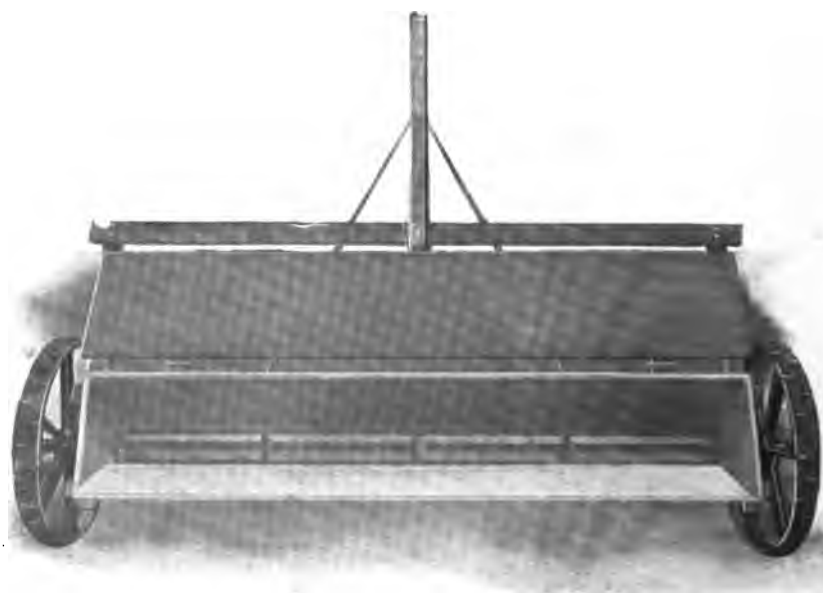
38% Lime	19% Phos- phoric Acid
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A Vermont Limestone Quarry
(Courtesy of the State Geologist)



LIME SPREADER.



THE LIME TRADE

The lime trade is in a somewhat demoralized condition, much as was the fertilizer trade in its earlier days. A name does not mean much, being unindicative. Thus, for example, the term "agricultural lime" does not indicate grade. A dozen samples reported in Massachusetts vary from 55 to 91 percent of lime; they carry all the way from 0.6 to 13½ percent magnesia; from no carbonic acid to 30 percent; and a hundred pounds of actual lime costs from 32 to 70 cents. Of seven quick limes six are straight limes and one is a dolomitic lime carrying 41 percent of magnesia to 57 percent of lime. Their cost ranges from 39 to 49 cents. Eight slaked or hydrated limes vary from 44 to 73 percent of lime; from 1 to 32 percent magnesium (one is strongly, two somewhat magnesian in character); and they cost all the way from 35 to 63 cents for a hundred pounds of actual lime. Four marls ran evenly, containing about 50 percent lime; three lots of "limoid" carry 42 to 49 percent lime and about 30 percent magnesia, costing 61 to 67 cents. Three lots of ground limestone carry about 50 percent lime or combined lime and magnesia (2 are dolomitic), costing from 60 to 74 cents; and several samples of "land lime" carry from 59 to 64 percent of lime, and 14 to 19 percent of magnesia and cost about two-thirds of a cent a pound for lime.

The bulletin in which these figures occur¹ contains an interesting table showing the cost of 100 pounds of lime and magnesia in Massachusetts markets. Their averages are:

Quicklime, 41 cts.; quicklime (ground), 46 cts.; marl, 56 cts.; slaked or hydrated lime, 56 cts.; ground limestone, 68 cts.; in each case the prices being f. o. b. at point of delivery.

COST OF LIME IN VARIOUS FORMS

Recent statements made in correspondence by Vermont sellers of lime as to rates at which they offer lime in its various forms are as follows:

¹Mass. Sta. Bul. 134 (1911).

Addison County. Green Mountain Lime Company, P. O. Middlebury, shipping point, New Haven Junction.

Prices f. o. b. cars New Haven Junction in carload lots.

Unslaked lime in bulk,	\$5 per ton.
Air slaked lime in bulk,	\$4 " "
Water slaked lime in jute bags,	\$6 " "
Air slaked lime in jute bags,	\$6 " "

Freight. Rutland railroad points, 4 to 9 cents per 100 pounds; Central Vermont railway points, 7 to 12 cents per 100 pounds; Boston and Maine railroad points, 10 cents per 100 pounds. Minimum carloads Boston and Maine, 30,000 pounds; Central Vermont and Rutland, 36,000 pounds.

Leicester Marble Lime Co., Leicester Junction. Lime f. o. b. bulk, carload lots, \$5 to \$7 per ton; waste lime, \$3.50 per ton.

Freight. Rutland railroad points, 8 to 9 cents per 100 pounds; Central Vermont railway points, 8 to 11 cents per 100 pounds; Boston and Maine railroad points, 10 cents per 100 pounds.

Chittenden County, G. B. Catlin, P. O., Burlington; shipping point, Winooski limekilns.

Quick lime in bulk, carload lots, delivered all Vermont points, \$7 per ton; in double headed barrels car lots delivered, 95 cents per barrel.

Air slaked lime (sifted) f. o. b. in carload lots, \$4 per ton.

Freight. Rutland railroad points, 5 to 9 cents per 100 pounds; Central Vermont railway points, 3 to 10 cents per 100 pounds; Boston and Maine railroad points, St. Johnsbury and Lake Champlain railroad points, Montpelier and Wells River railroad points, 10 cents per 100 pounds.

Franklin County. W. B. Fonda, St. Albans. Prices f. o. b. cars St. Albans, car lots.

Bulk lime, or slaked lime,	\$5 per net ton.
Either, barreled, at \$7.50 per net ton.	

Freight, most New England points, 10 cents.

Swanton Lime Works, Swanton. Hydrated lime, sacked, \$8 per ton delivered.

Hydrated lime, sacked, in less than carloads, \$6.50 f. o. b. Swanton.

Freight, all main line Vermont points, 8-10 cents per 100.

One of the lime burners states that they are "beset with calls for ground limestone"; but no one in Vermont as yet seems to be trying to meet this demand.

Windham County. Whitingham Lime Company, P. O. Greenfield, Mass., shipping point, Sherman, Vt. Prices f. o. b. cars Sherman.

Unslaked lime in bulk, \$5; in barrels	\$7	per ton
Air slaked lime in bulk, \$4; in barrels	6	" "
Air slaked lime in bags	5	" "
Fine ground, fresh burned lime in bags	6.50	" "
Fine ground, fresh burned lime in barrels	8.50	" "
Fine ground, fresh burned lime in bulk	6	" "

Freight. Boston and Maine points 10½ to 14½ cents.

Orleans County. H. F. Pillsbury & Son, Barton. Marl, screened, f. o. b. Sutton, in bulk carload lots (20 tons or more) \$2.85 per ton; same delivered, Boston and Maine points, \$4.60 per ton. Marl, screened, sacked in burlap, f. o. b. Sutton, carload lots (20 tons or more) \$4.50 per ton; same delivered, Boston and Maine points, \$6.10 per ton.

Windham County. Vermont Marl Co., Brattleboro. Shell marl, f. o. b. Caledonia, N. Y., in bulk carload lots (20 tons or more) \$3.50 per ton; same, sacked in burlap, f. o. b. Caledonia, N. Y., carload lots (20 tons or more) \$5 per ton.

Freight: \$2.25-\$3 per ton.

THE FUNCTIONS OF LIME ON SOILS AND IN PLANT GROWTH

Nitrogen, phosphoric acid and potash are deficient elements or compounds of plant food. The supply thereof gets low when soils are heavily cropped and plants become hungry for them.

That is why they enter into the composition of commercial fertilizers, why materials containing them in available forms constitute the so-called "direct" or "nutritive" fertilizers. Lime, on the contrary, while sometimes needed to supply a soil deficiency of that material, is more apt to be of service on account of its indirect action. In other words, it more commonly promotes plant growth through its effect upon the soil and the soil constituents as developed later on in this article on pages 413-428, than because it furnishes any needed plant food to the soil. Hence it follows that the functions of lime are many and somewhat complex and that, moreover, in order to possess an all round understanding of the bearing of the practice of liming on agriculture, one needs to consider its effect on the soil as well as on the plant. Few farmers understand its functions clearly or the special fitness of the different forms of lime to the needs of diverse soils and crops. Their lime selections are apt to be based on misunderstanding or on no understanding. Hence this article.

THE EFFECT OF LIME ON SOILS

The influence of lime on soils may be felt:

1. Upon its mechanical character. Pages 412-416.
2. Upon its chemical composition. Pages 416-423.
3. Upon its biological condition. Pages 423-426.
4. By means of its direct manurial effects Pages 426-427.
5. Injuriously. Pages 427-428.

In short, so far as the soil is concerned, lime displays physical effects, possesses chemical activities, influences the life of its lower organisms, may act as a fertilizer, or it may damage it.

I. MECHANICAL EFFECTS OF LIMING

The mechanical condition of a soil may be affected by liming in two ways. It may be opened up, made more loose, porous, friable; or it may be bound together and made more compact.

(a) *Flocculation of clays.* Every farmer who has properly used lime on heavy clay loams has seen the result as shown in their greatly improved porosity, their relative lightness, their

crumbly character. English farmers who are large users of lime say that its liberal application on clays enables them to plow with two horses instead of three. Its effect is more pronounced on clays and clay loams than it is on any other type, although when loamy soils are limed they are sometimes less likely to crust over and to dry out.

Wherein does a clay differ physically from a sand? What happens to an adhesive clay when it is limed? How is its coherence overcome? A clay may contain in the same weight of soil from 10 to 15 times as many particles or soil grains as are found in a sandy soil, the surface area of the particles occurring in a given weight may be ten times as great, and its pore space is greater. Clays are finer textured than sand, the arrangement of their soil particles is such that more empty spaces are left between them, and, hence, they hold more water and are more apt to become waterlogged, swelling when wet, heaving when frozen, and baking when dried. The penetration of plant roots is a difficult process in such compact soils, their healthy development is retarded, and they are torn when the soil heaves in the winter.

Furthermore, the tendency of such soils to puddle when plowed, that is to say so to change the arrangement of the soil particles as to inhibit the ready passage of water; their tendency to form hard clods; to erode or gully (see pages 148-150, bul. 135); all these tendencies are well known and undesirable. Clays are intractable, their tillage difficult, their service in farming operations while in their natural condition limited.

Now lime is a great ameliorator of all these conditions in that it flocculates clays, that is to say, gathers the fine particles into crumbs, a hundred, we will say, making one. This effect can be made visually evident if a little lime water is added to a glass of muddy water. The fine particles seem first to gather together into light fluffy groups or floccules, just such an occurrence as is seen when the big, feathery, compound snowflakes fall on a quiet winter's day. These floccules rapidly settle to the bottom of the glass, clearing the liquid. Lime is not

alone in producing this effect, for the sea water acts similarly. It is on this account that deltas are formed at river mouths by the flocculation of the river borne clays (see bul. 143, page 227). Lime, however, is the only practicable flocculating agent for use in agriculture. It is active and a little goes a long way. One part of lime as quicklime can flocculate and clear 10,000 parts of a turbid liquid. Hence one can calculate, and the calculation is borne out in practice, that a ton (35 bushels) applied to an acre,—the soil of which 6 inches deep may be expected to weigh not far from a 10,000 tons,—ought to have a marked effect.

Flocculation occurs whether quicklime, slaked lime or ground limestone is used, but the first two are more effective than is limestone. The results are seen quickly, although the work is not completed at once but goes on slowly for some length of time. It were well on this account, as well as on other accounts, to apply the lime some months, even a year or two, before the crop is sown which it is intended shall be benefited.

Liming is particularly serviceable on clay soils which are likely to gully. Such soils are quite apt to puddle, the fine particles washing away. But the flocculated particles of a limed soil "stay put" instead of running off, thus lessening the damage.

The cause or theory of flocculation is not well understood. Both chemical and physical agencies have been assigned; but whatever the philosophy of the phenomenon, the effect is clear, pronounced and most important. The percolation of water into and through the soil is markedly increased, the success of capillary action is enhanced, the pores are enlarged, a more rapid circulation of the water and air is secured, crusting and cracking are obviated, the proportion of the rainfall lost in the run-off is lessened, soils are warmed more quickly. In a dozen ways the soil is made better, chemically, physically and biologically.

Yet it is quite possible to overdo this matter, so frequently or so freely to lime as to make a soil hard and compact instead of friable and open, to make as it were a mortar bed instead of a seed bed. Such a condition of affairs, however, is uncommon. If the soil is very wet excessive applications of quicklime obviously may cause trouble. Underdrainage should precede its use in such cases.

There are thousands of acres in Vermont, especially in the Champlain valley and particularly in Addison county, which would be benefited by liming. Yet few farmers appreciate the fact, and such as do, as a rule, fail to understand that the application should be made in the fall rather than in the spring. Vermont farmers, accustomed for generations to haul manure in the spring and to buy commercial fertilizers in April, do not think of the fall as a proper time to apply a fertilizer. Liming in the spring may at times do more harm than good. In this connection see statement as to the practice of liming, pages 430-435.

(b) *Compaction of sands.* Sandy soils stand in far less need of lime than do the clays. Their faults are less surely remedied by these means. They do not need increased aeration; it is already excessive. The percolation of water should be retarded rather than hastened. Yet lime, applied in small amounts, may modify sandy soils favorably by compacting them and by increasing their retentiveness. It seems paradoxical that its effect should be exactly opposite to that wrought upon the clays, but such is the case. Ground limestone is probably the most desirable form of lime to apply to sands. Neither quicklime nor the two slaked limes should be used because of their tendency too rapidly to destroy the humus.

Clay marl has been used to good purpose. It tends more particularly to cement the soil particles and to retard moisture losses. However, its work as compared with that wrought on clay is of minor significance. It goes without saying that green manuring (see bul. 135, pages 169-175) is a desirable adjunct if farm manures are lacking or insufficient. Any treatment that

will tend to increase the organic content of such soils is advisable; but not at the same time that lime is applied.

2. CHEMICAL EFFECTS OF LIMING

The results produced by liming which may properly be listed under the head of chemical effects are manifold. That so powerful an agent should produce profound results is no cause for wonder. The more important effects, those having the greatest practicable bearing upon agricultural operations, may be stated as follows. The use of lime tends:

(a) To free certain forms of plant food, more particularly potash and phosphoric acid, from their soil combinations, thus rendering them more available to crop growth. Pages 416-418.

(b) To counteract the harmful effect of certain soil constituents, more particularly ferrous salts, a sour humus, and acids naturally present or accumulated because of faulty methods of soil handling. Pages 419-423.

(c) To modify the nature of excessive alkali formation. Page 423.

Concerning these diverse functions it may be said:

(a) *The liberation of plant food.* The plant food soil constituents ordinarily become slowly available to crop growth through the process of weathering and decay (see bul. 143, pages 205-215). Only a small proportion of the total amounts are thus made immediately serviceable. In cases where the totality is fairly ample but, because of incomplete weathering, of over-cropping, of leaching, or for other reasons, the proportion of available plant food is relatively low, thus unfavorably affecting crop yields, this situation may be temporarily rendered more favorable by the practice of liming. For lime frees considerable quantities of plant food, unlocks the combinations which hold it, increases its availability. This action is particularly effective in respect to potash and phosphoric acid, furnishing these constituents to crop growth from the soil itself rather than from extraneous sources, such as farm manures, commercial fertilizers or feeding stuffs.

This liberation of plant food constitutes the action of the "indirect fertilizer," and is helpful or is harmful according to circumstances; helpful if one does not overdo it, harmful if one does. It is easy to see that the results of liming may be harmful if the practice is continued for a series of years, since it is apt to lead to the relative exhaustion of the more available soil constituents. Or, to rephrase the statement, liming cannot be resorted to indefinitely, since it uses up plant food instead of furnishing it, drawing upon the soil stock instead of replenishing it. It is this danger of the overusage of lime which has given rise to the oldtime English proverb, "lime makes rich fathers and poor sons." Lime in this respect represents Ex-Governor Hoard's famous razor, with which one may either shave or cut his throat according to the way in which he handles it. It depends upon how lime is used, whether with a clear understanding of this danger or not, whether it does good or evil.

The potash of the soil exists mainly in insoluble or slowly soluble combinations. Drainage waters remove far less potash than they do of soda, magnesia or lime. Furthermore, potash salts are promptly fixed when sown, being changed to insoluble or difficultly soluble forms. When, however, the soil is limed or is naturally limy in its character, there appears to be an interchange of bases, lime substituting itself for potash, displacing it freely, making it soluble. Indeed there seems to be a sort of reciprocity between the two. If lime is in excess it frees potash and enters itself into its place; per contra, if potash is in excess and the soil content of lime is relatively low, the latter is partially freed and potash fixed in its place. Magnesia seems to act in much the same way.

This peculiar criss-cross reaction has been variously ascribed to the action of double hydrous silicates (zeolites), to double salts of humus acids, to the presence of iron and alumina hydrates, and to other causes. The disintegration and modification of the double silicates whereby soda, lime, potash, even ammonia, enter into their structure, seems to be due to what

might be termed chemical preferentialism. The silicates thus newly formed are relatively more available than they are in their original forms, and although they are subject to leaching, their plant food constituents are available to crop growth. Lime is held to have a favorable effect on the bringing about of these changes and on the formation of these desirable soil constituents. Whatever the cause, be it simple or complex, known or unknown, the result is clear, the potash is made more readily available to crop growth through the action of lime.

The phosphoric acid of the soil usually exists in the form of lime, iron and alumina phosphates, all highly insoluble, so much so that the ordinary drainage waters carry relatively small proportions. The lime phosphate is considerably more soluble in carbonated or pure waters than are the iron and alumina phosphates; consequently the more the lime phosphate and the less the iron and alumina phosphates, the more readily is the phosphoric acid available. Hence the amount of available phosphoric acid in a calcareous soil, other things being equal, is greater than that in a non-calcareous soil. That liming tends to increase the availability of the phosphoric acid of the soil has often been shown, the lime apparently attacking the iron and alumina phosphates. Magnesia seems to be quite as effective as is lime. The soluble phosphoric acid of an acid phosphate tends promptly to revert when sown upon a soil and to become relatively insoluble, the more so if the soil is ferruginous in its character and low in lime. This reaction may take place in as short a time as 24 hours. The phosphoric acid thus becomes thoroughly distributed throughout the soil, existing in a state of fine subdivision. Indeed this appears to be the main advantage derived from the use of acid in the manufacture of acid phosphate over the mechanical grinding of a raw phosphate. When lime is naturally in excess in the soil or is artificially added, the availability of added phosphoric acid is enhanced.

(b) *The correction of unfavorable chemical conditions.* It is now well recognized that at times soils contain bodies

inimical to plant growth, prominent among which are ferrous salts, organic and other acids and, perhaps, toxic bodies, more or less unknown in character. Concerning these it may be said:

Ferrous salts, particularly such as ferrous sulphate and compounds of ferrous iron with organic acids formed by the reduction of ferric salts, such as oxid and hydrate, etc., are commonly found in close textured subsoils and in swamp soils where the aëration is imperfect. The readiness with which such compounds use oxygen is advanced as a probable reason for the deterrent effect that soils thus laden exert upon vegetation. Liming tends to render such salts insoluble, to cause them again to assume the ferric form and, hence, to become relatively innocuous.

Soil acidity has been widely discussed of late in the public print and on the lecture platform. The once unappreciated fact, that many soils are acid, is now well understood and the relationship of such acidity to unsatisfactory crop growth is clearly apprehended. Its causes are many and in a given case one, two or more may be operative. The more important causes are:

1. The formation of sulphids.
2. The overuse of acidic forms of commercial fertilizers.
3. Selective absorption.
4. Acid decomposition.

1. The reduction of sulphates to sulphids is brought about in the soil by the presence of excessive amounts of decaying organic matter. It occurs particularly in marshy soils, in such lands as are washed by, or into which seep, acid waters. The damage which is done is wrought sometimes by the sulphid and sometimes by the sulphuric acid and the iron salts derived from their oxidation. Whichever condition obtains, lime or magnesia, either as oxid, hydrate or carbonate, serves as a corrective.

2. The application of excessive quantities of acid phosphate, its uneven admixture with the soil, or its overlarge use

on sandy soils, or on such as are relatively devoid of lime, may at times induce a temporary local acidity, to the extent of retarding or preventing the germination of the seed. Such difficulties are not as apt to occur on calcareous soils as on those which have been limed.

3. The selective absorption of bases by plant growth tends at times to produce soil acidity. By selective absorption is meant that process wherein a salt, for instance muriate of potash, is split asunder, its base, potash, being used by the plant, and its acid, hydrochloric acid, being left behind to accumulate in the soil. Plants use much more potash than they do of chlorin, and hence selective absorption often occurs. The hydrochloric acid, abandoned as it were by its former mate, quite often enters into combination with the lime of the soil, much of which passes into the drainage waters as chlorid of lime. At times, however, when soils are not limy and when potash salts are heavily used, an excess of acid may accumulate. Much the same thing happens when ammonium sulphate is used, sulphuric acid accumulating. While this may not be an important factor in causing soil acidity in many cases, it doubtless does function in some.

4. A common cause of soil acidity is to be found in the accumulation of acid forms of humus, a material resulting from the decomposition in the soil of such vegetable matter as the roots, stubble, farm manures, green manures and the like. The nature of this material was quite freely developed three years ago in bulletin 135, pages 153-175. It would seem on that account that nothing further need now be said touching humus as such. Furthermore, this proposition was discussed to some extent four years ago in bulletin 130, pages 229-236; in connection with the review of the causes of decomposition. The matter of soil acidity, however, has not been gone into at length in any bulletin issued at this Station and may well be reviewed here.

Several organic acids are formed in plant growth, such as oxalic, tartaric, citric. The sourness of the lemon, of rhubarb,

and of sorrel are well known. Several organic bodies are produced by plant life which may be said to be potentially acid, that is to say, they are capable on fermentation of producing acids. These include such common products as sugar, starch, gums, woody fibers, etc., which produce acetic, lactic, mucic, oxalic and other acids. And, finally, all of these plant constituents, when decomposing in the soil, may form humus compounds, many of which are distinctly acid. Some of these so-called humus acids have been cataloged in the past under such names as humic, ulmic, crenic, apocrenic and the like. Of late years, however, doubt has arisen as to whether these acids as a matter of fact are actual chemical entities. However, be that as it may, that many soils heavily laden with humus are on that account more or less acid, cannot be gainsaid. The organic matter in the soil slowly oxidizes, the organic tissues lose their identities, nitrogenous compounds, water, carbonic and other acids are formed. Humus accumulates in the colder latitudes, but is rapidly destroyed in the warmer climes. When conditions are such that the lime content of the soil is deficient, or when farm manures are applied in excessive amounts, or when a freshly turned under green manure is rapidly decomposing, acids may form in excess of the neutralizing power of the soil; and in such cases liming is a remedy.

Soil acidity tends to check the activities of the more helpful forms of bacteria, such as induce nitrification, the fixation of atmospheric nitrogen (page 424) and the liberation of plant food (page 416). Soil acidity is more common than is usually thought to be. A very considerable share of upland soils show acidity when tested, particularly those of a sandy type, those derived from the weathering of certain granites, even some soils of a limestone origin which become denuded of their lime by solution and by chemical agencies. It may best be diagnosed by observation, by experiment and by test.

Observation. The type of vegetation on a given soil furnishes a fair indication of its condition. When clovers

thrive, when root crops prosper, when most grasses do well, the soil is not apt to be seriously acid. On the other hand when these crops partly or wholly fail, acidity is likely, although not certainly, to be at fault. When sorrel, moss, bluets, horsetails, polypod brakes and white daisies abound, where wild blackberries grow readily, an acid condition may usually be suspected.

A study of the type of soil, as indicated on page 421, may serve to show whether or not it is likely to be acid.

Experiment. A beet crop may be used experimentally to find out if a soil is acid. If one wishes to determine the matter let him grow a row of beets. It can be grown right in with the corn or potato crop and needs no treatment or cultivation other than that which the regular crop receives. Let half of this row be limed and half left unlimed. If at the time of harvest the limed portion of the row yields a much better and bigger crop than does the portion left unlimed, there is every likelihood that the soil is acid.

Test. Soil acidity may be determined by the use of blue litmus paper, which may be bought at the larger drug stores. Litmus is a vegetable dye which is turned blue by alkali and pinkish red by acid. The results afforded by its use are not absolutely conclusive, for the reason that carbonic acid, which is a normal soil constituent, faintly affects this test; hence it is not proof positive of soil acidity. A satisfactory method of applying the test is that suggested by Wheeler¹ as follows:

"A teaspoonful or more of soil is placed in a tumbler or cup and moistened with sufficient water to make the mass of about the consistency of thick paste. Allow it to stand for 15 to 20 minutes before making the test. With a knife blade part the soil and insert one end of the strip of paper, press the soil about the paper and after 2 to 5 minutes remove the paper without tearing it. Rinse off the adhering soil with water and

¹R. I. Sta. Bul. 46, pp. 100-101 (1897).

note whether it still retains a blue tint or whether it has become positively red. If the soil has a reddish tint, it may be better to bring but one side of the paper into contact with it and if the red color comes through to the other side, it may be concluded that the soil is acid. Care must be taken not to handle the end of the paper used in making the test, since the touch of the fingers may retain it." A rain water is to be preferred for making the test as the use of well or spring waters which may be hard sometimes vitiates the result.

Lime or magnesia are admirable agents for the correction of the conditions discussed in the past two or three pages, a happy remedy for a desperate condition. Heavy applications may be made advantageously to mucky soils. They promote the rapid decomposition of the organic matter, furnish a readily available form of humus, increase its retentiveness for plant food, tend to render its nitrogen more available, promote bacterial action, especially nitrification. All these good things are wrought simply and solely by the neutralization of the acid which lessens the activity of bacterial growth.

(c) *The correction of excessive alkalinity.* Lime is used in the form of gypsum in arid regions as a corrective of certain alkaline soil conditions. The so-called "black alkali" consists mainly of carbonates, mostly of soda. The humus is rapidly destroyed by its accumulation. A heavy dosage of gypsum serves to change the noxious carbonates into the less harmful sulphates, the carbonic acid uniting with the lime forming calcium carbonate.

3. BIOLOGICAL EFFECTS OF LIMING

The biological (bacteriological) conditions of a soil may be markedly modified by the practice of liming in four ways, part of which have been discussed incidentally in other portions of this article.

a. It favors bacterial growth, promoting nitrification and nitrogen fixation. Page 424.

b. It serves on this account to "bring in" clover and to modify the character of the native vegetation. Pages 424-425.

c. It hastens the decomposition of humus. Page 425.

d. It affects insect life and fungus growths. Page 425-426.

a. *Bacteria*, their nature, functions and relations to the well being of crop growth were discussed at length four years ago in bulletin 130 now, unfortunately, long out of print. On account of this thorough treatment and of the statements hitherto made in this article, pages 419-423, it may be sufficient to say here simply that soil bacteria, which are minute plants, invisible to the eye and present in countless myriads in soils, are indispensable factors in plant growth; that a large share, although not all species, are helpful thereto; that soil acidity inhibits their growth; and that their well being is closely dependent upon a mildly alkaline reaction of the soil, a condition of affairs which is promoted by liming. Liming is apt to be particularly helpful in the nitrification of ammonia salts, which sometimes yield poor returns unless the soil is or is made alkaline.

b. *Nitrogen fixation* is a bacterial process (bulletin 130, pages 244-260). It is a necessary prerequisite to the satisfactory growth of clover and other legumes, and, as has just been remarked, bacteria thrive only where alkalinity obtains. Thus conditions which favor bacterial growth help legumes to grow. While clover failures are not always due to soil acidity, liming, in correcting soil acidity, (pages 419-423) in flocculating clays (pages 413-415) thus opening them up, bettering their drainage and hence lessening the likelihood of winter killing, more than any one thing is apt to prove a panacea as against clover failures.

As will be hereinafter stated, pages 428-430, lime has a very distinct effect upon the character of the native vegetation. Where lime or ashes are used a marked change is brought about in the kind of cultivated crops which may be successfully grown and, indeed, in the character of the weeds and

other natural vegetation. The more valuable grasses thrive, clovers grow more readily, sorrel tends to disappear and wild blackberries are less in evidence. It has often been observed that on adjoining plots, sown alike with clover and with timothy—one being limed, (whether with quicklime, slaked lime, ground limestone or gypsum, makes no difference), the other treated with nitrate of soda,—that the former seems, as judged by the appearance of the crop, as if it were sown to clover alone, and the latter as if it were sown to timothy alone. Both crops are actually present on both plots, but the crop most influenced by the fertilizer used,—for nitrate of soda is as much of a specific for grass as lime is for clover,—crowds out the other to such an extent as to make it a minor factor.

In passing from a non-limestone to a limestone soil one readily notes changes in the vegetation which are correlated with changes in the character of the soil. This is well seen, for instance, in passing across the State of Kentucky, where both the major and minor vegetation, the tree growth and the grass growth, seems to be determined according as the soil is or is not of limestone origin. In this connection see page 428.

c. The decomposition of organic matter and its transformation into humus as well as the breaking down of the humus into its constituent elements and simple compounds is enhanced by the use of lime, particularly on heavy soils in which such changes take place slowly. On light soils, however, which usually are relatively lacking in humus, liming may by its action on the humus do more harm than good. Lime is a well known disintegrator of organic matter, promotes nitrification, and affords a base wherewith may unite the nitric acid which is formed by bacterial action. In this disintegration and humus formation, carbonic acid is developed, which exercises a solvent action on the soil constituents, thus promoting their availability.

d. The spread of certain plant diseases, pests, etc., are affected by the use of lime. Thus, for instance, potatoes are more apt to be scabby when grown on soil which has been limed than

when planted on a soil not thus treated, provided the seed or the soil are infected. Lime of itself cannot cause potato scab; it simply tends to furnish a condition favoring its spread, provided infection is present. This is due to the fact that the condition of alkalinity induced by the use of lime tends to favor fungus growth just as it favors bacterial growth. This unfortunate result is brought about by all forms of lime except, perhaps, the sulphate (gypsum or land plaster). It is wrought by carbonate of lime as well as by the more acrid forms. On this account it is not wise to use lime immediately before a potato crop.

In quite a contrary way liming seems to inhibit the spread of the malady known as the club foot of cabbages, or at least decidedly to lessen the injuries which it induces. Excellent crops have been grown on soils which have been limed where previously only failures had been obtained. It is thought by some to exercise a deterrent effect upon insect life. Its relation to other maladies has also been studied, with inconclusive results.

4. THE DIRECT MANURIAL EFFECT OF LIME

Lime is one of the most abundant of substances in the whole realm of nature. About a sixth of the surface rocks are limestone and the element calcium comprises, perhaps, a sixteenth part of the structure of the earth's crust. Furthermore limestone rocks are relatively soluble and on this account lime has become well diffused throughout most soils. There are few soils too poor in lime adequately to feed crop growth for many years to come; few which have been so abused as seriously to reduce their lime content. Yet occasionally soils occur, sandy soils, slaty soils, certain residuary soils derived from rocks deficient in lime, such as sandstones, some schists, shales, and conglomerates, which may contain too little lime to nourish plant growth. Indeed some soils of limestone origin are benefited by liming, because of the removal of lime as carbonate, primarily by leaching and secondarily by plant growth, or because of the excessive solubility of lime salts found when

muriate of potash is freely and frequently applied. However, such soils are apt to be lacking not only in lime, but also in potash and phosphoric acid and not infrequently in nitrogen, and in supplying these deficiencies it usually happens that lime is incidentally supplied at the same time and in abundance.

Soil analysis is of but little avail in the determination of the question of the sufficiency of the supply of lime. Authorities differ as to what constitutes a sufficiency. Some place it as high as 1 percent, others as low as 0.10 percent. What is enough for one type of soil is an insufficiency for another type. Indeed, its total amount is less important than is its form, its activity. The best way to determine this matter is to undertake experimental trials such as are detailed on page 422.

5. INJURIOUS EFFECTS OF LIME

Lime may injure plant growth. So acid a material is it in quick or slaked forms that it well may do harm if used too freely or too often. In a series of trials reported by Voorhees and Lipman¹ crop yields were in some cases lowered by the use of lime. This result was thought to be due to one or more of the following causes: (a) Direct physiological interference with the assimilative process of the plant; (b) A lessened supply of available phosphoric acid induced by the free use of lime; (c) An accumulation of injurious substances due to increased bacterial action induced by the greater soil alkalinity; (d) The rapid exhaustion of some of the more available forms of plant food due to the increased numbers of soil organisms.

Lime is often suggested as a specific for alfalfa; yet in a series of trials reported by the Pennsylvania station² failures were frequent and the statement is made that "lime has not given satisfactory results. In some instances * * * it has been decidedly harmful." It is well understood that the harsher forms may burn

¹ N. J. Sta. Bul. 210, p. 78 (1907).

² Pa. Sta. Bul. 79, p. 4 (1906). It should be understood that the outcome is unusual.

seed. Thus Wheeler¹ found that hydrated lime, if applied just before the seed is sown to light soils even though they are acid, may hurt certain crops. This appears to be due to the injury to the roots, since no harm is done if the lime is sown some few weeks before the crop is put in. Lime as carbonate is less apt to injure crops than it is when it is applied in the cheaper but stronger forms.

THE EFFECT OF LIME ON PLANT GROWTH

Mineral matter is essential to plant growth. Lime constitutes an important part of this mineral matter. Thus average wood ashes carry 33 percent of lime. A 50 bushel crop of corn removes 12 pounds of lime from the soil, a two ton clover crop, 80 pounds, a 200 bushel potato crop, 200 pounds. Obviously lime enters into plant growth and doubtless it has its uses and its functions therein. These are, however, not always clearly defined. The two more obvious ones are:

1. It is apt to modify the form of the plant and to influence the character of the vegetation. Pages 428-429.
2. It unites with plant acids forming salts. Page 430.

1. THE MODIFICATION OF FORM AND CHANGE IN VEGETATION

A soil rich in lime, as compared with one in which this soil constituent exists in lesser quantities, is apt to be one on which plant growth is compact, sturdy, short-jointed, and with denser tops. Grains and grasses grown on limy soils seem somewhat less likely to lodge than those grown on soils less rich in this ingredient, their greater strength being presumedly due to their environment. The forest growth on limestone soils is more sturdy, thicker set, its branches shorter and stronger than is the forest growth of similar species on a soil not calcareous in its character. Ecological investigations have clearly shown the relationship between the character of the forest growth and the lime content of the soil. The oak and the ash are characteristic trees of limy soils. Lime appears to be a governing

¹ R. I. Sta. Bul. 121, p. 175 (1907).

factor as regards the vegetation in many cases. Indeed, Hilgard goes so far as to state that "a soil must be considered as being calcareous whenever it naturally supports the vegetation characteristic of calcareous soils."¹ Lime seems furthermore to assist in the formation of cellulose and to aid the fruit and the grain.

The growth of some plants seems to be helped and that of others to be checked by the use of lime. Thus we have the so-called calciphiles and calcifuges, the lime loving and the lime avoiding crops. Among those which are usually helped by liming, or which grow best where soils are somewhat calcareous in their nature, are the foliaceous crops, as a class; most vegetables; most root crops, particularly beets; most cereals; most legumes, particularly clovers, alfalfa, peas and beans, etc. Among the crops which are quite apt to be injured by liming or when grown on the soils carrying much lime, may be mentioned millet, red top and blackberries. In some experiments corn has been but little benefited, in others it has been helped. It is not a crop which seems particularly sensitive to acid. Potatoes are not apt to be materially benefited although the size of the crop may be increased; on the other hand the probability that infection from potato scab would be increased ought to discourage its use. It is not considered good practice to lime a soil just before a potato crop is grown. (See page 426). Among the fruits, apples, pears, peaches, plums and cherries, and tomatoes among the vegetables, are not greatly benefited by liming though not in the least injured thereby. Beets and clover in particular thrive exceptionally well on limy soils or when lime is employed. The common wood sorrel thrives on soils ill supplied with lime or on those which have become acid, being injured or destroyed when lime is applied. This plant is often used as an indicator of the need of liming, although it is not infallible, since it grows at times even after a heavy liming. A good

¹ "Soils," p. 496 (1906).

growth of sorrel declares its necessity; a good growth of beets indicates that it is not needed. (See page 423).

2. THE FORMATION OF LIME SALTS

Lime enters into the plant sap uniting therein with several plant acids, neutralizing them wholly or in part. Thus one finds calcium oxalate (lime and oxalic acid) in beet leaves, and calcium malate (lime and malic acid) in maple sap, forming the well known "sugar sand" or "nitre."

THE PECULIAR FUNCTION OF GYPSUM

One form of lime, the sulphate (gypsum or land plaster), whether a natural product or an artificial one, exercises a function which the other forms do not. It is a fixer or fastener of ammonia through its power of forming with that material compounds which do not evaporate. Lime drives off ammonia, but plaster holds it. When mixed with decaying nitrogenous organic matter, the loss of nitrogen in the form of ammonia resulting from that decay is decidedly lessened. Plaster is therefore used to quite an extent on piles of fermenting manure or in stables. When used in the barn it is sprinkled in the powdered form in the trenches behind the cattle, perhaps a third of a pound daily to an animal being used. The reasons for its beneficial action are not well understood, and, sometimes, it unaccountably fails to accomplish its work.

Gypsum also tends to favor the progress of the nitrifying process, and, like other forms of lime, frees potash and phosphoric acid (as mentioned on pages 416-418). Indeed it is perhaps more efficient in this latter capacity than are the other forms of lime. It may also to a limited extent flocculate clays, (see pages 413-415), but is less serviceable for this purpose than is either quick or air slaked lime.

THE PRACTICE OF LIMING

WHEN TO LIME

It is usually thought to be wise to use lime in connection with or well before the planting of lime-loving crops such as

roots, foliaceous crops other than corn, clover, and legumes; but not before the planting of those crops which are injured by lime such as potatoes, millet, rye, etc. Ashes, marls and other carbonates, as well as gypsum or land plaster, may be used at any time of the year without injury, but the fall is the safest, possibly the only safe, time to apply on most soils the more acid forms, such as quick and slaked lime. Acid or peat soils may often be benefitted by large applications in the spring, but ordinarily the fall is much the safer time. These stronger forms of lime, if applied in too large quantities, particularly in the spring when there is little time for them to be altered through exposure to the air into the milder carbonates, may act so vigorously as to endanger vegetation and, indeed, to some slight extent to hinder rather than to favor bacterial activity. An injury of this character, however, is usually of a temporary character, since in due time through air slaking further injury is obviated and the alkalinity of the soil is reduced. Stress is laid upon this matter since most farmers in Vermont who have of late years practised liming, make the mistake of considering it, as for generations they have been considering the usage of other forms of fertilizers, as a material to be sown in the spring. Fall sowing is the almost universal custom in those sections where liming is an old practice and is very much to be preferred here.

Lime should never be used in connection with an ammonia salt, with organic nitrogen, or with soluble phosphoric acid. It is a common thing for farmers to mix wood ashes with hen manure. This makes the hen manure more drillable, but drives off much costly nitrogen. It is a mistake likewise to mix lime or ashes with a commercial fertilizer containing soluble phosphoric acid, as it tends to make this material again insoluble.

HOW OFTEN SHOULD ONE LIME? HOW MUCH SHOULD BE USED?

Circumstances govern. One certainly should not lime in consecutive years and ordinarily it is not applied more than once in

from four to eight years. For the correction of acidity or to improve the mechanical condition of a soil, a single application suffices for several years, and then, later, light dressings applied at wide intervals serve to maintain texture and alkalinity.

However, it should be said that practice varies according to the kind of soil, the amounts used, the form of lime, the length of rotation and the crops which are grown. Speaking broadly, from one to two tons used once in from five to seven years are apt to meet most cases; the larger amounts to be used on the heavier and the smaller on the lighter soils.

WHAT FORM OF LIME SHALL BE USED?

Clearly no one form is best for all the different soils and conditions which are met. Soil, crop, climate, location, season of application, market price, means available for its application, cost; all these affect the choice. Quicklime is usually the cheapest available lime. It is, however, much the most disagreeable to handle. It does anything that any other form of lime can do, save land plaster, which can be used in the stable to hold ammonia, whereas quicklime drives off ammonia. When slaked lime, limekiln ashes, marl or impalpably ground carbonate of lime may be purchased at fair prices, these may be preferable. The slaked lime and the lime kiln ashes are not as powerful as is the quicklime, nor is the marl or carbonate as powerful as the slaked lime. However, one can buy for a dollar more pounds in the form of slaked lime, of marl, or of finely ground carbonate, than he can of quicklime. It may frequently occur that one dollar spent for one of the milder forms may produce in the long run quite as serviceable results as a similar sum spent for agricultural lime as such. Moreover, the milder forms are much more readily spread and are handled with less difficulty. If one desires to sweeten a soil any form may be used, other than gypsum or land plaster. If one particularly wishes to free plant food in any soil, or if one wishes to furnish lime which is thought to be deficient in the soil, any form may be used; if

one wishes to fix ammonia in the stable or in fermenting manure, gypsum should be used, as the other forms drive off ammonia. These general suggestions may be epitomized as follows:

WHAT FORM OF LIME SHOULD BE CHOSEN?

For heavy soils for the improvement of their mechanical condition; oxid or hydrate (quick or slaked).

For lighter soils; carbonate (ground limestone or marl).

For stable use; sulphate (gypsum, land plaster).

To get the most for a dollar; oxid (quick lime).

To use in the fall; oxid or hydrate, carbonate or sulphate.

To use in the spring; carbonate or sulphate, rarely the oxid or hydrate.

To spread the easiest; carbonate or sulphate.

To cause the most discomfort to man and beast; oxid.

All things considered, economy, ease of handling and service; oxid, slaked at the farm, fall spread with special spreaders.

If the use of lime is delayed until spring; usually carbonate, unless the buyer is well informed as to the dangers of the use at that time of the stronger forms.

MANNER OF APPLICATION

In those sections of the country where liming is a common practice it is customary to plow the soil, to spread the lime upon the surface somewhat evenly using a lime spreader, and then to harrow it in. If, however, the sod is very heavy, sometimes half is put upon the sod and plowed under and the other half put on as a top dressing and harrowed in. The manner of application naturally varies somewhat with the conditions and the form of lime used. Where animal husbandry obtains and soil acidity is not a factor, land plaster is frequently the best form in which to apply lime, using it by way of the stables.

In cases of direct application, however, the lime may be either spread on the surface and turned under, sown on the furrow, and harrowed or disked in, spread from small heaps checker-boarded over the field, or from a grain drill with a fer-

tilizer attachment, or from a lime spreader. The first of these procedures is not as common as and, perhaps, is less advisable than the second. Whatever system is used and whatever form of lime is applied, effort should be made to have the particles as fine as possible and to mix them thoroughly with the soil. When quicklime is used it is well to slake it shortly before using (see page 403). If the lime is to be spread from these heaps, and it is desired to use a ton to the acre, twenty-pound heaps may be made twenty feet apart each way, covering each with moist earth or with dry earth after moistening each pile, or with about a quarter of a pail of water for slaking. Even spreading should be done. Lumps may be screened or picked out. The lime should be harrowed in promptly after it is spread lest it cake with the soil forming a sort of mortar. Eyes, nose and mouth must be protected from the lime dust (see page 403).

Quick or slaked lime is a disagreeable material to spread by hand or otherwise. Manure spreaders have been used but not in a very satisfactory manner. Lime spreaders are on the market being made by the manufacturers of fertilizer drills. A home made one is thus described by Thorne¹ which seems to have been a satisfactory device. (See plates opposite page 409).

"Make a hopper similar to that of an ordinary grain drill, except that it should be 8 feet long with sides and top 18 to 24 inches wide. Let the bottom be 5 inches wide in the clear and cut in it a row of oval holes, one inch wide, two inches long and 8 inches apart. Make a false bottom with holes in it of the same size and shape as those of the main bottom, and so spaced that they will register. Let this false bottom slide loosely under the hopper, moving upon supports made by leaving a space for it above bands of strap iron, which should be carried around the hopper every two feet to strengthen it. Both bottom pieces should be of smooth, seasoned hardwood, $\frac{3}{4}$ to $\frac{7}{8}$ inch thick and well oiled or painted. To this under strip, or

¹Ohio Sta. Bul. 159, pp. 193-4 (1905).

plate, rivet a V-shaped arm, extending an inch in front of the hopper, with a half inch hole in the point of the V, in which drop the end of a strong lever, bolting the lever loosely but securely to the side of the hopper, 3 or 4 inches above the bottom. Let the lever extend 6 or 8 inches above the top of the hopper, and fasten to the top of the hopper a guide of strap iron, in which the lever may move freely back and forth. The object of this lever is to regulate the size of the openings by moving the bottom plate. Make a frame for the hopper, with a tongue to it, similar to the farm of an ordinary grain drill.

Get a pair of old, mowing machine wheels, with ratchets in the hubs, and two pieces of round axle of sufficient length to pass through the wheels and frame and into the ends of the hopper, where they are welded to a bar of iron $1\frac{1}{4}$ inch in diameter and the length of the inside of the hopper. The axles should be fitted with journals, bolted to the underside of the frame.

Make a reel to work inside of the hopper by securing 8 short arms of $\frac{1}{4}$ inch by $\frac{3}{4}$ inch iron to the axle, and fastening to these 4 beaters or wings of $\frac{1}{4}$ inch by $\frac{5}{8}$ inch iron, and about an inch shorter than the inside of the hopper, the reel being so adjusted that the wings will almost scrape the bottom of the hopper but will revolve freely between the slides. These arms may be made of two pieces, bent so as to fit around the axle on opposite sides, and secured by small bolts passing through the ends and through the beater which is held between them. The diameter of the completed reel is about 5 inches and its length an inch or so less than that of the inside of the hopper. This reel serves as a force feed.

Tack two pieces of oilcloth to the bottom of the hopper, one in front and one behind, of sufficient width to reach the ground. These are to reduce the annoyance to man and team of the flying lime dust." See the cuts of this spreader opposite page 409.

SUMMARY

The practice of liming is rapidly increasing in New England. Vermont produces about \$200,000 worth annually, used mostly for building purposes, but increasingly in agriculture. Pages 388-391.

Lime occurs as carbonate (limestone, marl, etc.), sulphate (gypsum, land plaster), and phosphate; and, when artificially made, is used as oxid (quick or burned lime), hydrate (slaked lime, hydrated lime) impure hydrate (air slaked lime), impure carbonate (ashes of sundry sorts), phosphate (acid phosphate, basic slag), and sulphate (gypsum, land plaster). Pages 391-408.

Lime costs delivered from about 40 to about 70 cents per 100 pounds, according to the form in which it is bought. Pages 409-411.

The functions of lime on soils are diverse. It displays mechanical effects, flocculating clays; possesses chemical activities, freeing plant food and neutralizing acidity; influences soil micro-organic life, favoring bacterial and fungus growth and promoting decomposition; may act as a fertilizer; or it may hurt the soil. Pages 412-428.

Its effect in plant growth is to modify its form and quite decidedly to determine its character; and to neutralize plant acids. Pages 428-430.

Liming is ordinarily practiced before the planting of lime-loving crops; as a rule in the fall; on acid or mucky soils; occasionally rather than regularly, using relatively large amounts. The form of lime chosen varies according to circumstances. A spreader works well as a means of applying lime, but it may be spread by hand. A description of an effective home made lime spreader appears on pages 434-435. So much damage may be done by the ill advised use of lime that he who contemplates its use for the first time should carefully study the practice of liming lest he err. Pages 430-435.

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VERMONT AGRICULTURAL
EXPERIMENT STATION

BURLINGTON, VT.

BULLETIN No. 161

JANUARY, 1912

FOREST SERVICE PUBLICATION No. 9.

Hemlock in Vermont
Comparative Study of Log Rules

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FOREST SERVICE PUBLICATION NUMBER 9
BULLETIN 161: HEMLOCK IN VERMONT
COMPARATIVE STUDY OF LOG RULES

By A. F. HAWES, STATE FORESTER

PART I. HEMLOCK IN VERMONT

INTRODUCTION

According to a report of the United States Forest Service for 1909 the average annual lumber cut in Vermont is 351,000,000 board feet, 123,000,000 of which are spruce and 62,000,000, hemlock. These two species together, therefore, constitute over half the present lumber output.

A detailed discussion was made by the writer a year ago of the management of white pine forests¹, a type which is at present not extensive in Vermont, but which will be of increasing value as time goes on and which should always be encouraged. A matter of more immediate importance in Vermont is the management of spruce forests, such as must always cover the greater part of her mountain areas. The United States Forest Service has long been securing data on spruce and the results of its studies, shortly to be published, will furnish the basis for a bulletin on the management of spruce. Pending the issuance of these data it seems worth while at this time to devote a publication to hemlock, because of its present importance in Vermont's lumber business and of the questions concerning management which arise.

RANGE

Hemlock occurs throughout Vermont from the northern boundary to the Massachusetts line, being formed in the valleys and on the mountain slopes, although it does not ascend the mountains as high as does the spruce. Neither is it characteristic of the plains as is the pine. It prefers the lower slopes of the mountains and the sides of cool ravines. Hemlock does not occur

¹ Vt. Sta. Bul. 156 (Forest Service Publication No. 4) (1911).

here in pure forests and, consequently, is nowhere of prime importance. It is usually found mixed with such trees as spruce and basswood on the steeper rocky slopes, with birch, maple and beech on the richer soils, and with pine in the Connecticut and Champlain valleys. It is now being lumbered in many forests where the original pine or spruce has been cut off and the hemlock left on account of its inferiority. Most of it is of old original growth, as indicated by the table of ages (page 8).

VOLUME TABLE

The most accurate method of timber estimation is by the use of the so-called volume tables, tables based on the measurement of a great many felled trees.¹ Thus far reliable American volume tables have been constructed for only a few species. The data upon which the following hemlock volume table was constructed, was secured in 1910 by the careful measurement of 320 felled trees in the towns of Granville, Rochester and Danville, thus representing two quite widely separated regions. The trees measured were felled for regular logging operations and were sawed into twelve foot logs. The measurements taken as the basis of the table were: diameters both inside and outside the bark at the top of each log. From these figures obtained in the field each log was scaled in the office by the Vermont rule and the total contents of each tree obtained in board feet. The trees were then classified according to diameter and height and each group was averaged. The averages were then evened off by a curve and final results obtained which appear in the following table. The italicised figures represent the average volume of each diameter class regardless of height; and for ordinary application, where the heights of standing trees are not known, these figures may be assumed to be correct.

¹ See such tables for white pine in Vt. Sta. Bul. 156, pp. 117-118 (Forest Service Publication No. 4.) (1911).

TABLE I. VOLUME TABLE FOR HEMLOCK IN BOARD FEET: VERMONT RULE

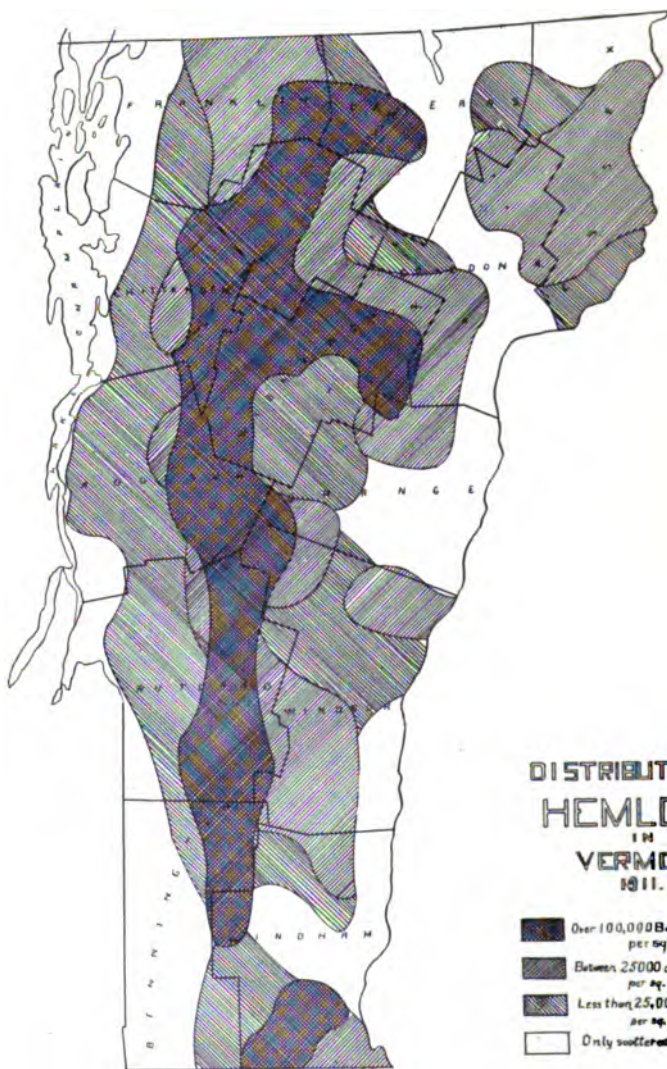
Diameter at breast height	Total height of tree						
	40 feet	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet
	Board feet						
8 inches,	35						
9 inches,	42	51	60				
10 inches,	53	66	76				
11 inches,	66	81	94	109	120		
12 inches,	74	93	113	132	153		
13 inches,		118	132	156	180		
14 inches,		140	160	182	214	241	
15 inches,		160	185	217	248	284	
16 inches,			214	248	282	320	
17 inches,			250	283	317	360	
18 inches,			293	330	364	405	454
19 inches,			335	372	408	450	500
20 inches,			380	415	454	498	545
21 inches,				455	497	545	590
22 inches,				491	540	594	650
23 inches,				520	582	650	710
24 inches,					626	712	780
25 inches,					675	777	836
26 inches,					742	840	906
27 inches,					790	897	968
28 inches,						978	1040
29 inches,						1040	1100
30 inches,						1100	1160

If this volume table is compared with that given for white pine¹ it will be found that the two do not greatly differ.

TABLE II. COMPARATIVE VOLUMES OF PINE AND HEMLOCK OF CERTAIN SIZES

	White pine, board feet	Hemlock, board feet
Trees 10 inches in diameter, 50 feet high.....	75	66
Trees 15 inches in diameter, 60 feet high.....	195	185
Trees 15 inches in diameter, 90 feet high.....	340	284
Trees 20 inches in diameter, 80 feet high.....	485	454
Trees 25 inches in diameter, 80 feet high.....	715	675
Trees 27 inches in diameter, 90 feet high.....	905	897

¹ Vt. Sta. Bul. 156, p. 117 (1911).



It will be noticed that the figures for pine are invariably higher than those for hemlock. While this may be partially due to the characteristic forms of the two species, it is also undoubtedly due to the fact that the volume table for pine is based on mill tallies, while the hemlock table is based on the Vermont rule, which considerably underruns the mill tallies, especially for large logs, as is shown on page 32.

Hemlock has always been an important source of tanning material on account of the tannic acid in its bark. While there are now many substitutes, large quantities are still used; and the bark of a hemlock forest may furnish a considerable revenue. Hence in order to estimate the total value of a hemlock stand, it is necessary to be able to determine the amount of bark as well as that of lumber. The following volume table for bark was constructed by subtracting the volumes of the trees inside the bark from their volumes outside the bark, and multiplying by .4¹ on the assumption that 40 percent of a stacked cord of bark, as it is ordinarily stacked, is solid bark.

TABLE III. VOLUME TABLE FOR HEMLOCK BARK IN STACKED CORDS

Diameter at breast height	Volume of bark in cords	Diameter at breast height	Volume of bark in cords
8 inches,	.03	19 inches,	.20
9 inches,	.05	20 inches,	.22
10 inches,	.06	21 inches,	.25
11 inches,	.07	22 inches,	.28
12 inches,	.08	23 inches,	.31
13 inches,	.09	24 inches,	.34
14 inches,	.10	25 inches,	.37
15 inches,	.12	26 inches,	.40
16 inches,	.14	27 inches,	.43
17 inches,	.16	28 inches,	.46
18 inches,	.18	29 inches,	.50

A comparison of this statement with table I shows that the ratio between lumber and bark varies. For example 1,000 board feet of 10 inch trees would peel according to table III, 0.90 of a

¹ Schenck, "Forest Mensuration," p. 14 (1905). The accuracy of this factor was borne out by our investigations of a few piles of bark.

cord of bark, while 1,000 board feet of 20 inch trees would peel 0.48 of a cord of bark. It is a common practice of lumbermen to consider that 1,000 board feet of hemlock will yield a half cord of bark.

AGE OF HEMLOCK

Most Vermont hemlock is old growth that has escaped cutting either because of the inferiority of the lumber or its inaccessibility. The figures upon which this study were based were all obtained from such old growth trees; hence the average ages as given for different diameters do not indicate the possible growth at any definite age, but the actual ages of the trees as they run in the woods throughout the state. Hemlock is very tolerant of shade and will persist under a dense cover, making almost no growth where other species would die. On this account small size is no indication of youth, many suppressed trees not over a foot in diameter being two hundred years old.

TABLE IV. AVERAGE AGE OF HEMLOCK

Diameter at breast height	Age	Diameter at breast height	Age
8 inches,	140 years	19 inches,	230 years
9 inches,	150 years	20 inches,	238 years
10 inches,	159 years	21 inches,	246 years
11 inches,	167 years	22 inches,	254 years
12 inches,	175 years	23 inches,	262 years
13 inches,	183 years	24 inches,	270 years
14 inches,	190 years	25 inches,	278 years
15 inches,	198 years	26 inches,	286 years
16 inches,	206 years	27 inches,	294 years
17 inches,	214 years	28 inches,	301 years
18 inches,	222 years	29 inches,	310 years

While the above figures indicate the astonishingly slow increase of old growth hemlock, as a matter of fact other tolerant species occurring under similar conditions are equally aged. Old growth spruce, for example, as studied in New Hampshire was found to average 94 years at 4 inches breast height, 225 years at 20 inches, etc.; while second growth spruce under more favorable conditions of light and moisture showed a fairly rapid rate of increase.



Thrifty hemlock left for the protection of a watershed, although mature.



Forest belonging to the Vermont Sanatorium, Pittsford, from which the poorer beech and large hemlock have been removed to help the growth of the remaining stand. This cutting resulted in a good profit.

The following tables of values is based on the two preceding volume tables and on the age table and shows how slowly old growth hemlock increases in value.

TABLE V. VALUE OF HEMLOCK FOR DIFFERENT DIAMETERS.

Diameter	Average age	Volume	Volume of the bark	Value of lumber at \$5 per M ³ stumpage	Value of bark at \$1.50 per cord ¹	Total value of tree standing
8 inches,	140 years	35 bd. ft.	.03 cords	\$0.17	\$0.05	\$0.22
9	150	42	.05	0.21	0.07	0.28
10	159	66	.06	0.33	0.09	0.42
11	167	94	.07	0.47	0.10	0.57
12	175	113	.08	0.57	0.12	0.69
13	183	156	.09	0.78	0.13	0.91
14	190	182	.10	0.91	0.15	1.06
15	198	217	.12	1.08	0.18	1.26
16	206	248	.14	1.24	0.21	1.45
17	214	317	.16	1.58	0.24	1.82
18	222	364	.18	1.82	0.27	2.09
19	230	408	.20	2.04	0.30	2.34
20	238	454	.22	2.27	0.33	2.60
21	246	497	.25	2.49	0.37	2.86
22	254	540	.28	2.70	0.42	3.12
23	262	630	.31	3.15	0.46	3.61
24	270	712	.34	3.56	0.51	4.07
25	278	777	.37	3.88	0.55	4.43
26	286	840	.40	4.20	0.60	4.80
27	294	897	.43	4.48	0.64	5.12
28	301	978	.46	4.89	0.69	5.58
29	310	1040	.50	5.20	0.75	5.95
30		1100		5.50		6.35

From these figures it will be seen that a tree ten inches in diameter is worth twice as much as is an eight inch tree, but that it takes 19 years for the value to double; that a tree eighteen inches in diameter is worth twice as much as one fourteen inches in diameter but that it requires 32 years to achieve this gain; that a twenty-seven inch tree is worth twice as much as a twenty inch

¹ Of course the values of standing trees vary according to their situation. It should not be understood that hemlock lumber is always worth \$5 per thousand stumpage, or bark \$1.50 per cord, but simply that at these prices standing trees of various sizes would be worth the prices given in the final column.

tree and that this doubling in value requires 56 years. Since a doubling of value in 16 years represents only $4\frac{1}{2}$ percent compound interest, it will be seen that the growth of hemlock throughout its age to maturity represents a very poor investment.

FORM FACTOR OF HEMLOCK

So-called "form factors" for all important species have been constructed in Europe. These are extensively used there in timber estimating. Where volume tables exist they are unnecessary, but at the same time they furnish a very interesting standard by which to compare the forms of various species.

A form factor is the ratio of the volume of a tree to that of a cylinder of the same base and height. In the construction of the form factor given below the volume of the cylinder was obtained by multiplying the area of the cross section at breast height by the total height of the tree. It will be readily seen that a form factor is always a fraction, and that the more tapering a tree the smaller is this fraction. For convenience it is expressed as a decimal. Inasmuch as trees make their main height growth first and then thicken out, it will be understood that the form factor usually increases with the age of a tree after the main height growth has been finished. Form factors made for the hemlocks of different diameters and heights employed in this study, did not vary appreciably. This relative uniformity was probably due to the fact that the trees were all practically mature and that their trunks were equally filled out. This form factor for hemlock based on 314 trees is .547. The form factors for balsam fir, based on 94 trees, is stated as .457¹. Evidently hemlock is much fuller boled than is fir. Graves² gives tables of form factors for several European species. As a matter of interest for comparison with Vermont hemlock the form factor of Norway spruce over 90 years old is shown as follows:

¹ Forest Quarterly I., p. 57 (1903).

² "Forest Mensuration," p. 407 (1908).

TABLE VI. FORM FACTOR OF NORWAY SPRUCE OVER 90 YEARS OLD

Diameter breast high in inches	Form factor	Diameter breast high in inches	Form factor
4	.559	20	.427
8	.505	32	.367
12	.475	40	.354
16	.449		

Since the hemlock form factor is based largely on trees between 12 and 20 inches in diameter, a comparison with the spruce figures for these diameters shows that the hemlock tapers less than does the Norway spruce, that, in other words, a hemlock of the same diameter and height would saw out more than would a fir or Norway spruce. Unfortunately no form factor is extant at present for native spruce.

TAPER TABLES

While form factor tables are interesting as showing the comparative forms of different species, they are not as valuable as a means of timber estimating in this country, where the board foot is the standard of measurement, and where innumerable log rules obtain, as they are in Europe where cubic measure is the rule.

For our purpose, as a means for the construction of a volume table by any of the various log rules, a taper table is the most universally useful method of expressing the average form of trees of different dimensions. A taper table is made by classifying together all trees of the same diameter at breast height, and of the same height, as, for example, all trees fifteen inches in diameter and between fifty-five and sixty-five feet in height. The diameters of these various trees at the top of each twelve foot log are averaged and the results for the various classes evened by a curve. The final table therefore, gives the top diameter of each twelve foot log of the average tree of each diameter and height class.

[illegible]

TABLE VIII (Continued)

Top diameters of 12 foot logs, in inches

Diameter at breast height	Trees 80 feet high Number of logs from stump (1st) to top						Trees 90 feet high						
	1st	2nd	3rd	4th	5th	6th	1st	2nd	3rd	4th	5th	6th	7th
13	11.2	10.3	9.1	7.4	5.0	2.1							
14	11.7	10.8	9.7	8.0	5.4	2.2							
15	12.8	11.7	10.3	8.4	5.6	2.3							
16	13.2	12.2	10.9	9.0	6.3	2.8	13.3	12.4	11.4	10.0	7.9	4.9	1.5
17	14.1	12.8	11.6	9.7	6.6	2.6	14.2	13.1	12.1	10.5	8.2	5.0	1.0
18	14.9	13.7	12.3	10.2	7.3	3.3	15.0	13.9	12.7	11.0	8.5	5.7	2.2
19	15.6	14.6	13.2	11.1	7.8	3.3	15.7	14.6	13.3	11.6	8.9	5.5	1.8
20	16.2	15.1	13.5	11.2	7.7	3.1	16.5	15.7	14.4	12.6	9.8	6.0	1.4
21	17.0	16.0	14.4	12.1	8.4	3.5	17.4	16.6	15.3	13.3	10.4	6.8	2.4
22	17.9	16.8	15.3	13.0	9.2	4.0	18.1	17.3	16.2	14.4	11.4	7.1	2.1
23	18.8	17.5	15.8	13.5	9.7	4.4	19.8	18.2	16.9	15.0	12.0	7.8	2.5
24	19.6	18.2	16.5	13.0	10.0	4.4	20.3	19.0	17.4	15.4	12.5	8.0	2.4
25	20.4	18.9	17.2	14.4	10.2	4.6	21.4	19.8	18.2	16.2	13.0	8.4	2.5
26	21.3	19.7	18.0	15.2	10.9	4.7	21.8	20.6	17.1	16.9	13.7	8.9	3.0
27	21.8	20.4	18.7	15.9	11.4	5.2	22.3	21.1	19.5	17.3	13.9	8.9	3.0
28	22.9	21.5	19.5	16.6	12.3	5.4	23.9	22.5	20.5	17.9	14.0	9.0	3.0
29							24.9	23.0	20.8	18.1	14.3	9.2	3.1
30							25.5	23.6	21.4	18.6	14.7	9.5	3.1
31							26.4	24.4	22.0	19.0	15.0	10.0	3.5

APPLICATION OF VOLUME TABLE

The following table based on the measurements of an acre in Danville is given as an illustration of a typical acre in which hemlock forms an important part of the stand, and also to show the use of a volume table.

TABLE VIII. STAND OF ONE ACRE HEMLOCK AND HARDWOODS, DANVILLE, VT.

Diameter at breast height	Number of trees per acre				Volume of hemlock, board feet	
	Hemlock	Maple	Birch	Beech	Per tree from table I	Total
5 inches,	2	4	3			
6 inches,	1	3	2			
7 inches,		4	1			
8 inches,	4	2	1		35	140
9 inches,	3	7		1	42	126
10 inches,	1	6		1	66	66
11 inches,	1	5	2		94	94
12 inches,	1	1	2		113	113
13 inches,	1	5			156	156
14 inches,	4	2	5		182	728
15 inches,	2	3	2		217	431
16 inches,	3	2		1	248	744
17 inches,	2		1		317	634
18 inches,	4	1	1		364	1456
19 inches,	1		2		408	408
20 inches,		1	1		454	
22 inches,	2				540	1080
23 inches,	2		1		650	1300
24 inches,	2				712	1424
26 inches,	2				840	1680
29 inches,	2				1040	2080
	40	46	24	3		12,173

By the use of the volume table the total stand of hemlock on this acre is estimated at 12,000 board feet. This may be considered as a very good stand, for although many better may be found, most forests have much less hemlock per acre.

REPRODUCTION

Wherever hemlock seed trees are plentiful, reproduction is usually fair. It does not, however, take possession of old pastures as do the pine and spruce, and it is practically never found on the burns on the mountains where poplar, birch, and spruce are so common. Hemlock, however, seems to possess the ability to reproduce on a hardwood litter of leaves better than do either pine or spruce, and frequently young hemlocks are seen starting under old hardwoods. An example of such reproduction is given below. But while there is considerable small reproduction of hemlock there is almost no second growth in the stage so commonly found of spruce and pine. Hence figures of the increment of second growth hemlock are entirely lacking. Indeed it is doubtful whether there will ever be another growth of any account to take the place of the old trees.

TABLE IX, SHOWING REPRODUCTION OF HEMLOCK UNDER MAPLE, 1/16 ACRE, IN DANVILLE, VERMONT

<i>Maple</i>										
Diameter breast high in inches,	2	3	4	5	6	7	8	9		
Number of trees,	7	3	3	3	8	5	5	1	Total, 35	

<i>Hemlock</i>										
Height—feet,	1	2	3	4	5	6	7	8	9	10 11
Number of seedlings,	1	1	3	11	14	21	15	14	4	2 1 Total, 87

The following reproduction studies by forestry students of the University of Vermont, while made with no special reference to hemlock, show very well the relation existing between hemlock in the main stand and the reproduction.

Series A, numbers 1 to 6 inclusive, was made on Sam's mountain, west of Brattleboro, on the east and west slopes of this ridge which has a north and south direction.

1. An open stand with light shade; soil well drained and gravelly.

Species	Percentage of trees in main stand	Percentage of seedlings in reproduction
Beech	85%	90%
Hemlock	4%	8%
Maple	4%	Pine 2%
Black cherry	1%	
Birch	5%	
Hornbeam	1%	
	100%	100%

2. Soil rocky; shade dense.

Species	Percentage of trees in main stand	Percentage of seedlings in reproduction
Hemlock	85%	95%
Maple	13%	White pine 5%
Beech and birch	2%	
	100%	100%

3. Exposure east and south; soil rocky, light and well drained.

Species	Percentage of trees in main stand	Percentage of seedlings in reproduction
Hemlock	69%	2%
Maple	15%	
Beech	5%	98%
Pine	3%	
Birch	7%	
Ash	1%	
	100%	100%

4. Exposure east and south; shade dense.

Species	Percentage of trees in main stand	Percentage of seedlings in reproduction
Hemlock	45%	100%
White pine	45%	
Maple	4%	
Birch	6%	
	100%	100%

5. Steep exposure east and south.

Species	Percentage of trees in main stand	Percentage of seedlings in reproduction
Black oak	70%	Sprouts 5%
Hornbeam	10%	75%
Maple	15%	
Hemlock	5%	20%
	100%	100%

6. Exposure west; shade medium, soil shallow.

Species	Percentage of trees in main stand	Percentage of seedlings in reproduction
Hemlock	65%	30%
Elrch	20%	30%
White pine	3%	
Maple	4%	10%
Ash	6%	30%
Cherry and oak	2%	
	100%	100%

Series B. was taken on a hillside in Barnet with a northern exposure.

7. Level land near stream at foot of slope; soil a wet, heavy black loam.

Species	Percentage of trees in main stand	Percentage of seedlings in reproduction
Fir	30%	17%
Hemlock	22%	15%
Maple	15%	10%
Cedar	11%	25%
Ash	10%	23%
Pine	6%	10%
Yellow birch	3%	
Black cherry	3%	
	100%	100%

8. Gentle north slope; soil a heavy loam.

Species	Percentage of trees in main stand	Percentage of seedlings in reproduction
Maple	35%	32%
Yellow birch	18%	15%
Fir	14%	10%
Hemlock	11%	10%
Beech	7%	3%
Basswood	6%	11%
Ash	5%	12%
Others	4%	7%
	100%	100%

9. Northwest slope, steeper and better drained than 7 and 8; soil a rich loam; stand much denser than 7 and 8 and reproduction was scarce.

Species	Percentage of trees in main stand	Percentage of seedlings in reproduction
Hemlock	38%	60%
Maple	16%	8%
Fir	16%	
Beech	10%	20%
Yellow birch	8%	5%
Basswood	5%	4%
Ironwood and cedar	7%	3%
	100%	100%

10. Situation similar to the preceding, but the stand, which was largely of hardwoods, had been considerably cut into so it was not nearly as dense.

Species	Percentage of trees in main stand	Percentage of seedlings in reproduction
Maple	30%	32%
Yellow birch	24%	7%
Hemlock	10%	6%
Fir	8%	9%
Beech	7%	
Ash	6%	20%
Others	15%	26%
	100%	100%

These ten canvasses throw much light on the matter of hemlock reproduction and the proportion which it forms of the whole reproduction of a stand under varying conditions. Thus in studies 2, 4 and 9 where the shade was dense, hemlock formed from 60 percent to 100 percent of all the reproduction; while in studies 1, 6 and 10 where there was plenty of light, it formed only 6 percent to 30 percent thereof. In other words, few other species are able to reproduce under dense shade as well as hemlock. Maple and beech rank next in their ability to reproduce under shade.

The occurrence of seedlings is not the only controlling feature in the formation of a second generation. Rapidity of height growth is quite as important. For this reason table x is of interest.

TABLE X.¹ SHOWING THE AGE OF HEMLOCK SEEDLINGS OF DIFFERENT HEIGHTS

Height, feet	Age, years	Height, feet	Age, years	Height, feet	Age, years
4	18	7	24	10	30
5	20	8	26	11	31
6	22	9	28	12	32

Measurements which have been taken of the growth of pine seedlings indicate that they reach the height of five feet in about half the time that hemlock requires, and that after that they grow relatively still faster. While figures dealing with spruce growth are lacking, numerous observations lead to the belief that its growth lies between those of pine and hemlock. This slow growth of hemlock is the controlling factor of its future in our forests. In the original forests where sheer persistence, so to speak, and ability to live under the densest shade, were chief requisites, the hemlock stood unchallenged. But with the inroads of lumbermen upon our forests new conditions have been brought about. The forest floor is no longer densely shaded. Other species, more rapid growing than is the hemlock, can now

¹ This table is based on 100 seedlings measured on the lot described by table ix.

thrive, and to the energetic tree today belongs the forest, just as to the energetic man belongs success in business. This is why second growth stands of pine, spruce and hardwoods are found, but rarely of hemlock.

SOUNDNESS

Seventy-eight percent of the three hundred old growth hemlocks studied were absolutely sound, while 22 percent were more or less decayed. Rot occurred almost entirely at the butt. In some cases a butt log 10 or 12 feet long had to be discarded, but usually the rot did not extend over 6 feet up the tree. Many of the trees included in this 22 percent were only beginning to show signs of rot at an age of 200 or 250 years, while many others were perfectly sound at 300 years. It was impossible to discover any relationship between size and the beginning of rot, for since all the trees studied were mature the smaller ones seemed to be quite as apt to be decayed as the larger ones. This, of course, would not be true of younger, growing trees. Similar observations on spruce in various parts of Vermont lead to the conclusion that this species is much more apt to be decayed than hemlock and that it cannot safely be left to such an advanced age as hemlock. The spruce is quite as apt to be affected above as below with red rot, which is due to a fungus, *Trametes pini*. It is not known whether the fungus causing the rot in hemlock is the same species or not, but it must be borne in mind that all tree rots, like other forms of decay, are due to some one organism or to organisms, and, therefore, are liable to spread from one diseased tree to another.

MARKET CONDITIONS

Hemlock lumber is coarse grained and is principally used for dimension material, the frames for buildings, planks for bridges, etc. Considerable quantities are also made into boards, part of which are planed and matched. It is used in the making of butter boxes in Vermont. Hemlock logs delivered at the mills bring from \$9 to \$12 per thousand board feet. Probably \$10 is

an average price. The sawed lumber f. o. b. the car at the mill brings from \$16 to \$18 per thousand board feet, a little less than is paid for the same grade of spruce. At \$10 for logs at the mill it is clear that only under the most favorable circumstances and at points convenient to the mill, is it possible to realize \$5 per thousand stumpage on hemlock. In the majority of cases \$4 may be considered a fair stumpage price.

Hemlock bark was in great demand in the past. In some parts of the country trees were cut and peeled for their bark alone, and the logs left to rot in the woods. Substitutes for bark for tanning purposes, especially the extracts from South America, have largely taken its place, and relatively lumber is now of more importance. In some of the more inaccessible sections of Vermont hemlock bark is not utilized, but in most lumber operations the hemlock is cut in the early summer when it can be easily peeled, and the bark is shipped either to Boston or Morrisville. Bark is bought by the cord, but on the basis of a cord being equivalent to 2,240 pounds. The price paid usually varies from \$6 to \$7 per cord f. o. b. the car, or from \$7 to \$8 delivered, the average price f. o. b. being probably \$6.50. Large quantities of bark are shipped annually to Morrisville from Newport, Lyndon, Montpelier, Barre, Middlesex, Waterbury, Stowe, Bethel, Bradford and points as far south as White River Junction and as far north as Sherbrooke, P. Q.

It costs from \$2 to \$3 a cord to cut hemlock trees and peel and pile the bark. Probably \$2.50 is an average cost. On a good down hill road two cords of bark can be hauled to a load, so that the cost of hauling varies from about \$2 for a five mile haul to \$2.50 for an eight mile haul. It costs about 25 cents a cord to car the bark. Evidently the cost of the bark f. o. b. the car may easily range from \$4.50 to \$6 per cord, leaving a stumpage value to the owner, acting as his own operator, varying from nothing to \$2.50 per cord. Probably \$1.50 per cord is an average value. Obviously \$1 a cord for bark on the stump would be

an outside price to pay unless it was exceptionally well located as regards haul and freight charges.

MANAGEMENT

The foregoing statements make it clear that hemlock is extremely slow growing, that it is of less value than are some of the more rapidly growing species, notably pine and spruce, and that it is not forming second growth forests as are several species. Such being the case but one form of advice can be given to owners of standing hemlock, namely, to cut out the hemlock and see that the land is covered with some more profitable species. In many cases natural reproduction of pine, spruce or fir can be obtained by leaving a sufficient number of seed trees. It should be explained, however, that fir is a more valuable tree to raise than is the hemlock because it is so much more rapid growing; not because of any superiority of its lumber. If it requires seventy-five years to produce a certain amount of hemlock lumber and the same amount of fir can be raised in forty years, the natural advantage of fir will be readily recognized. Figures are so far lacking to prove just what is this relationship between hemlock and pine, spruce and fir, but they will certainly be to the disadvantage of hemlock. To secure natural reproduction of spruce and fir one should understand that not only are several seed trees per acre of those species necessary, but that the ground cover must be favorable for a germinating bed. These species, especially the spruce, do not start well on hardwood leaf litter, because their roots must reach mineral soil at an early age and they are unable to penetrate a thick layer of leaves. For this reason most of the hardwood trees should be cut, except such as are needed to protect the spruce seed trees from windfall, a precaution which is quite necessary in view of the fact that the spruce has a shallow root system and is especially apt to be thrown over when left exposed. It might at first seem that it would be a good plan to burn the leaves. This, however, is not good policy when reproduction of spruce, fir or pine is sought,

since burned areas are almost sure to be preempted at once by such light seeded species as poplar, paper birch and bird cherry to the exclusion of the slower growing softwoods. Where reproduction of these species is impossible on account of lack of seed trees, such a growth of poplar or paper birch may well prove more profitable than the present growth of hemlock. However, it is usually desirable to *plant* one of the more valuable species where desirable reproduction cannot be secured. On sandy land, pine should be planted; on the heavier soils and at higher elevations, Norway spruce may be recommended.¹

It is not intended in this bulletin to be too radical with the hemlock. Most farmers wish to have in their woodlots enough softwood lumber to rebuild their set of buildings in case of fire. This is good economy, and where hemlock is the only softwood present in sufficient quantity it should be reserved. We would advise such farmers, however, to get an area started to pine or spruce as soon as possible, and to cut all unnecessary hemlock to a diameter of fifteen inches at most. They should realize that the money they can get from their hemlocks will yield them much bigger interest if invested in a young plantation, or in a savings bank, and would probably furnish more adequate fire protection if placed in a fire insurance policy.

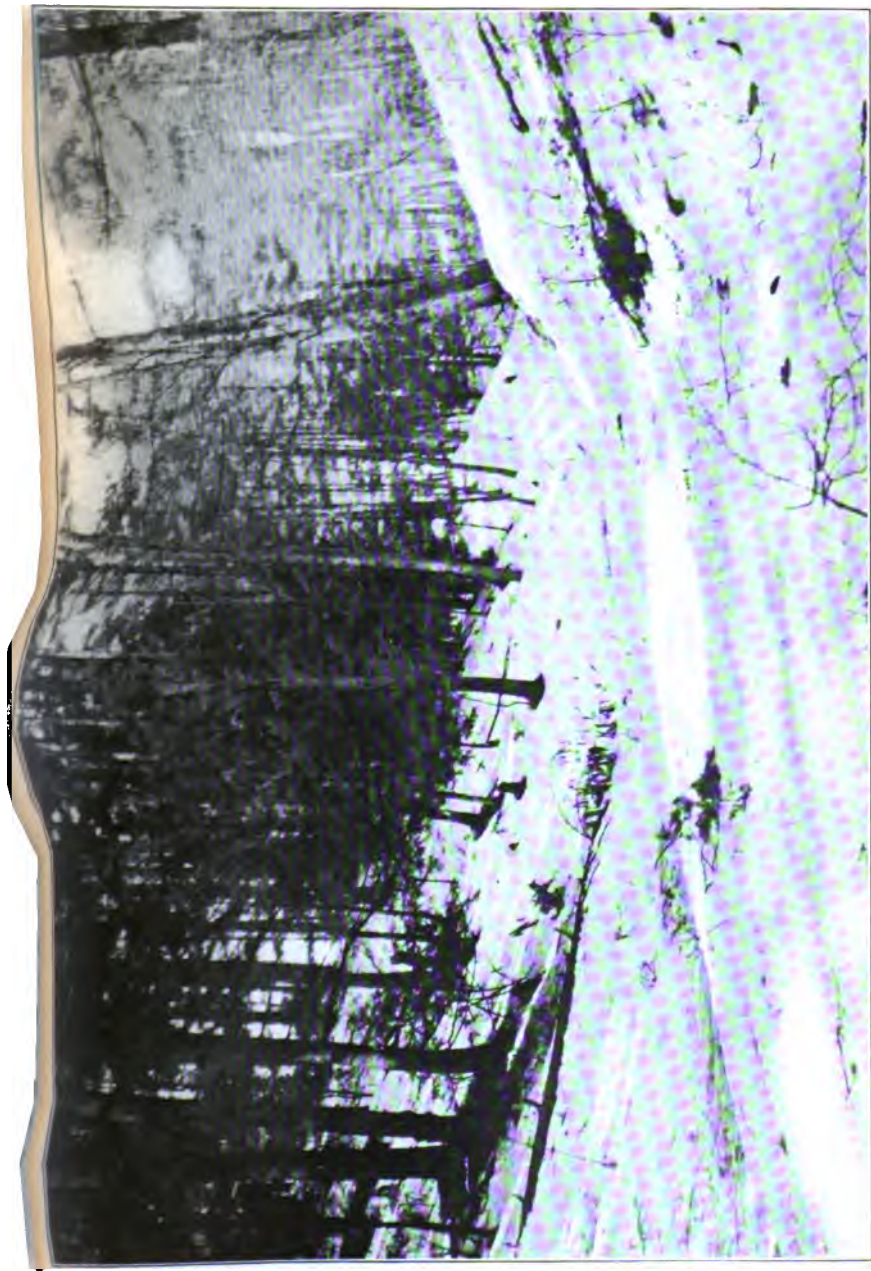
Hemlock is a very beautiful tree because of its dark green foliage; hence groves of large hemlock trees are very desirable in estate forests. Some splendid examples occur near Burlington. This class of forests, owned by wealthy men for their beauty rather than for their commercial value, will be much more common in Vermont in the future than they are at present. Owners of forests suitable for such purposes should realize that trees often have a value to wealthy men far in excess of their lumber value, and should be governed accordingly. However, in most locations it will not pay to keep unproductive capital for the doubtful prospect of a land boom.

¹ See Vt. Sta. Circs. 4 and 6—Forest Service publications 3 and 5—(1910, 1911).

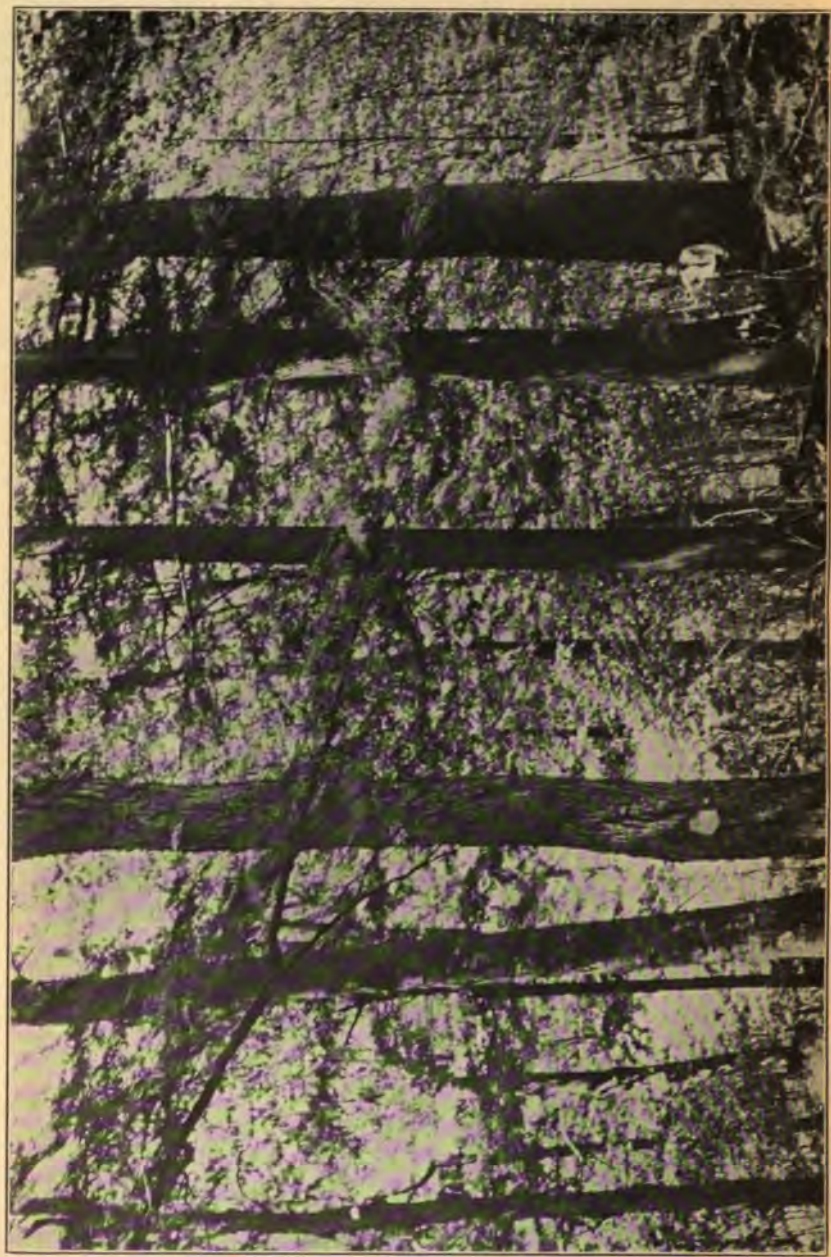
Hemlock often occurs on very steep slopes, especially on the banks of streams, and on the lower ridges of mountains. On such situations trees should never be cut clean since soil wash is inevitable, and the runoff of water is made more irregular. Extensive cuttings of this nature cannot but effect spring freshets and summer droughts of springs and brooks. Public policy demands that such situations should always be kept covered with forest and the selection system¹ should, therefore, be practiced. That most land owners are unfortunately more or less selfish and desirous of handling their forests for profit instead of for the public good, should be recognized as only natural. This is the reason why such lands, especially the main range of the Green mountains so essential for its effect on runoff, should be owned by the State and preserved in a way not practicable for the private holder.

Except where forests are needed for their protective value or are valuable for aesthetic reasons, it may be laid down as an economic principle that it is nearly as bad to have a considerable portion of the State covered with overmature, unproductive forest as to have it lying idle covered with brush. As an example it may be assumed that there are at least 500,000 acres of waste land in Vermont, and possibly 500,000 acres of overmature timber. This leaves about 2,500,000 acres covered with growing forest of more or less value. Of course the overmature timber is by no means all hemlock, but all overmature timber is unproductive and the principle holds that the State is losing the income from a million acres, if the above figures are correct, whereas the income from this land, if covered with thrifty growing forest, could be from \$2,000,000 to \$5,000,000. It must not be supposed that there is no growth in an old stand. The point is that, through death and decay, as much or more timber is destroyed in an uncared for old forest in a year as grows in the same time.

¹ See Vt. Sta. Bul. 156. (Forest Service Publication No. 4) (1911).



A cool ravine, which is the typical site of hemlock.



Overmature hemlock and hardwoods marked to be cut so as to make room for younger and faster growing trees.

PART II

COMPARATIVE STUDY OF LOG RULES¹

In order to get accurate data on the correctness of some of the log rules in use in Vermont in comparison with actual mill tallies, 159 soft wood logs have been measured at the mill and the amount of lumber sawed from them noted. Tables xi, pages 26-31, and xii, page 31, give the results of this study.

¹ A "log rule" or log scale is a table which purports to give the volume in board feet of logs of various diameters and lengths. Log rules are made in various ways, some from diagrams, others from actual mill tallies, and still others from mathematical formulae. The latter method of constructing log rules is the most accurate method. Of course the accuracy of the results attained in a given case depends upon the formula used.

The statutes of Vermont make the "Vermont rule" the legal scale. This rule is based on the premise that the board foot contents of a 12 foot log are equal to the product of the small diameter by half of itself.

Board feet = $D \times \frac{D}{2} \times \frac{L}{12}$ where D = diameter at the small end in inches and L = length of log in feet.

Thus for an 8 foot log, 16 inches at the top:

$$\text{Board feet} = 16 \times \frac{16}{2} \times \frac{8}{12} = 16 \times 8 \times \frac{2}{3} = 85.$$

One of the most common log rules in use throughout the country is the Doyle rule, sometimes wrongly called the Scribner rule. This

is based on the formula: Board feet = $\left\{ \frac{D-4}{4} \right\}^2 \times L$

By this rule the tree described above would have the following contents:

$$\text{Board feet} = \left\{ \frac{16-4}{4} \right\}^2 \times 8 = 9 \times 8 = 72.$$

Prof. A. L. Daniels of the University of Vermont has published the Champlain rule which is based on the formula:

$$\text{Board feet} = \frac{3.1416}{5} \times D^2 - D \frac{L}{12}$$

$$\text{Example: } \frac{3.1416}{5} \times 16^2 - 16 \times \frac{8}{12} = 97.$$

TABLE XI. MILL SCALE OF 12 FOOT SPRUCE LOGS SAWED INTO 1½" LUMBER

Diameter, top end, inches	Number of log	Board feet	Total	Average scale per log, 1½" boards	Scale by Ver- mont rule, 1" boards	Scale by Doyle rule, 1" boards	Scale by Cham- plain rule, 1" boards
8	1	41					
	2	37					
	3	36	114	38	32	12	32
9	4	42					
	5	45					
	6	48	135	45	40	19	42
10	7	48					
	8	42					
	9	57					
	10	60					
	11	56					
	12	65					
	13	49					
	14	60					
	15	53	490	54	50	27	53
11	16	78					
	17	78					
	18	78	234	78	60	37	65
12	19	88					
	20	84					
	21	88	260	87	72	48	78
13	22	95	95	95	84	61	93
14	23	121					
	24	118	239	119	98	75	109
15	25	138	138	138	112	91	126

TABLE XI. MILL SCALE OF 12 FOOT HEMLOCK LOGS SAWED INTO 1" BOARDS

Diameter, top end, inches	Number of log	Board feet	Total	Average scale per log, 1 1/4" boards	Scale by Ver- mont rule, 1" boards	Scale by Doyle rule, 1" boards	Scale by Cham- plain rule, 1" boards
7	26	28	28	28	24	7	24
8	27	41					
	28	33					
	29	40					
	30	30	144	36	32	12	32
9	31	44					
	32	39					
	33	40	123	41	40	19	42
11	34	76					
	35	70	146	73	60	37	65
12	36	95	95	95	72	48	78
14	37	120	120	120	98	75	109
15	38	127	127	127	112	91	126
16	39	143					
	40	123					
	41	140	406	135	128	108	145

MISCELLANEOUS SOFTWOODS, 12 FEET LONG, SAWED INTO INCH BOARDS

Diameter, top end, inches	Number of log	Board feet	Total	Average scale per log, 1' boards	Scale by Ver- mont rule, 1' boards	Scale by Doyle rule, 1' boards	Scale by Cham- plain rule, 1' boards
4	42	15	15	15	8		6
5	43	22					
	44	18	40	20	12	1	10
6	45	16					
	46	22					
	47	21					
	48	28					
	49	27					
	50	32	146	24	18	3	17
7	51	31					
	52	24					
	53	24					
	54	22					
	55	23					
	56	27					
	57	29					
	58	28	208	26	24	7	24
8	59	33					
	60	41					
	61	36					
	62	37	147	37	32	12	32
9	63	48					
	64	58	106	53	40	19	42
10	65	43					
	66	65	108	54	50	27	53
11	67	75	75	75	60	37	65
12	68	75					
	69	79	154	77	72	48	78
13	70	92	92	92	84	61	93
14	71	121	121	121	98	75	109
15	72	88					
	73	150	238	119	112	91	126
17	74	158	158	158	144	127	165

MISCELLANEOUS SOFTWOODS, 13 FEET LONG, SAWED INTO INCH BOARDS

Diameter, top end, inches	Number of log	Board feet	Total	Average scale per log, 1" boards	Scale by Ver- mont rule, 1" boards	Scale by Doyle rule, 1" boards	Scale by Cham- plain rule, 1" boards
4	75	14					
	76	18	32	16	9		6
5	77	15					
	78	19					
	79	17					
	80	17					
	81	20					
	82	25	113	19	13		11
6	83	22					
	84	16					
	85	21					
	86	19					
	87	26					
	88	30					
	89	30					
	90	30	194	24	19	3	18
7	91	26					
	92	25					
	93	37					
	94	30					
	95	32					
	96	30					
	97	34					
	98	31					
	99	36					
	100	38					
	101	49	368	33	27	7	26
8	102	38					
	103	38					
	104	36					
	105	40					
	106	39					
	107	41					
	108	39					
	109	40					
	110	40					
	111	42					
	112	42					
	113	46					
	114	48					
	115	55	584	42	35	13	35

Diameter, top end, inches	Number of log	Board feet	Total	Average scale per log, 1" boards	Scale by Ver- mont rule, 1" boards	Scale by Doyle rule, 1" boards	Scale by Cham- plain rule, 1" boards
9	116	35					
	117	38					
	118	39					
	119	43					
	120	49					
	121	50					
	122	54					
	123	52					
	124	62					
	125	54	476	48	44	20	45
10	126	29					
	127	38					
	128	45					
	129	53					
	130	53					
	131	55					
	132	51					
	133	58					
	134	60					
	135	65					
	136	75					
	137	90	672	56	54	29	57
11	138	74					
	139	64					
	140	68					
	141	67					
	142	79					
	143	86	438	73	66	40	70
12	144	75					
	145	87					
	146	85					
	147	90					
	148	88					
	149	100	525	87	78	52	85
13	150	120					
	151	113					
	152	113					
	153	115	461	115	92	66	101
14	154	105					
	155	137	242	121	106	81	118
15	156	156	156	156	122	98	137

Diameter, top end, inches	Number of log	Board feet	Total	Average scale per log, 1" boards	Scale by Vermont rule, 1" boards	Scale by Doyle rule, 1" boards	Scale by Champlain rule, 1" boards
16	157	176	176	176	139	117	157
17	158	174	174	174	157	137	178
20	159	216	216	216	175	208	251

TABLE XII. TOTAL CONTENTS OF ALL LOGS MEASURED—BY MILL SCALE, VERMONT, DOYLE AND CHAMPLAIN RULES

All logs 4 to 12 inches diameter (inclusive)

Diameter, top end, inches	Total number of logs	Total mill scale board feet	Total by Vermont rule	Total by Doyle rule	Total by Champlain rule
4	3	47	26		18
5	8	153	102	..	86
6	14	340	260	42	246
7	20	604	513	140	502
8	25	989	527	197	527
9	18	840	760	172	786
10	23	1270	1198	645	1267
11	12	893	756	452	810
12	12	1034	906	600	978
Total,	135	6170	5048	2248	5220

The mill tallies of the boards from these 159 logs as they came from the saw were almost all in excess of the scale as determined by any of the three log rules used. It is possible that some boards were tallied somewhat high as there is a tendency among some mill men to tally high when custom-sawing. As a rule, however, the tallies here given may be considered fair. It will be noticed that for many of the small logs the Vermont and Champlain rules corresponded closely with the mill tallies; while the Doyle, or Scribner rule as it is sometimes called, always gave very low results. It is evident that no one should

TABLE XII. TOTAL CONTENTS OF ALL LOGS MEASURED—BY MILL SCALE, VERMONT, DOYLE AND CHAMPLAIN RULES

All logs 13 to 20 inches (inclusive)

Diameter, top end, inches	Total number of logs	Total mill scale board feet	Total by Vermont rule	Total by Doyle rule	Total by Champlain rule
13	6	648	536	386	590
14	6	722	604	462	672
15	5	659	570	462	641
16	4	582	523	441	592
17	2	332	301	264	343
18					
19					
20	1	216	175	208	251
Total,	24	3159	2709	2223	3089
Total of all logs,	159	9329	7757	4471	8309

sell logs by this rule. Unfortunately a comparatively small number of large logs were measured.

Table xii shows that 135 logs between 4 and 12 inches in diameter sawed 6,170 board feet; that the total scale of these logs by the Vermont rule was 5,048 board feet or 82% of the mill scale; by the Doyle rule 2,248 board feet or 36 percent of the mill scale; and by the Champlain rule 5,220 board feet or 85 percent of the mill scale. The total mill scale of the 24 logs between 13 and 20 inches was 3,159 board feet. The scale by the Vermont rule was 2,709 board feet, or 86 percent of the mill scale; by the Doyle rule 2,223 board feet or 70 percent of the mill scale; by the Champlain rule 3,089 board feet or 97 percent of the mill scale. While the results by the Vermont and Champlain rules do not vary appreciably when used on small logs, there is a distinct difference when applied to large logs. The Champlain rule is, therefore, much the more accurate for all purposes.

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VERMONT AGRICULTURAL
EXPERIMENT STATION

BURLINGTON, VT.

BULLETIN NO. 162

JANUARY, 1912

Plant Diseases in 1911

Potato Spraying Experiments in 1911

BURLINGTON:
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**BULLETIN 162: PLANT DISEASES IN 1911
POTATO SPRAYING EXPERIMENTS IN 1911**

By B. F. LUTMAN

PLANT DISEASES IN 1911

The summer of 1911 was remarkable for its very high temperature and scanty rainfall, especially during July and the first half of August. As a consequence of these meteorological conditions, plant diseases were rare. Those epidemic diseases such as brown rot of plums, orange leaf rust of the blackberry and the mildews, which spread as a result of high humidity, were checked early in the summer and in many cases it was rather difficult to find specimens. The grain rusts, also, seemed to be much less abundant than usual.

The early and late blights of the potato plant were not reported during the summer and no cases were observed. Tip-burn, resulting from the very hot, dry weather, was disastrous on light sandy soils around Burlington. By August 5, those plants that had not been sprayed had lost in many instances at least two-thirds of their leaf surface. Tip-burn appeared from ten days to two weeks earlier than usual on account of the unusual conditions. The rains of August 15 and 18 revived the plants somewhat, but they never recovered from the drought of the earlier part of the season. The weather chart of the three months of July, August and September, 1911, shown on page 40, clearly brings out the very high temperature of July and August and the scanty precipitation from July 7 to August 15.

An attempt was made to ascertain the percentage of oat smut likely to be found nowadays in Vermont oat fields. Judging from the appearance of the fields around Burlington it was thought that the percentage would be found to be rather high. Reports from six widely separated regions were made by students of the College of Agriculture. Actual counts were made in fields by the barrel hoop method. The amount of smut has apparently not increased since 1892 and 1893 when it was estimated to be from 1 to 3 percent.¹ The fact that home grown seed is largely used in Vermont is doubtless responsible for this gratifying sit-

¹ Vt. Sta. Rpts. 6, pp. 73-82 (1892); 7, pp. 60-65 (1893).

uation. Indeed, it was noted that where western or foreign seed was sown the percentage of smutted heads was higher. Treatment of the seed for oat smut is not worth what it costs when the proportion of smut is so low.

An interesting apple disease appeared on Baldwins and Greenings and was often reported. The affected fruit showed sunken spots over the surface of a darker hue than that of the surrounding skin, that is to say of a darker red or a darker green, depending on the location of the spot, which, however, were never brown. In most cases these spots extended only a few cell layers below the epidermis and were of a dry and corky nature. Apparently these spots were the true "stippenflecken" described by the German stations¹, being quite different from the Baldwin fruit spot as described by Brooks.² Specimens were also received wherein corky dry streaks extended from the surface to the core following in general the vascular system. These are more nearly similar to those described by Jones³, in 1898. The extreme dry weather of July and August, the period of growth of the fruit, doubtless induced these physiological diseases. It has been found in Germany that these "stippenflecken" of apples are more numerous in very dry seasons.

POTATO SPRAYING IN 1911

The potato spraying experiments of 1911 were a continuation of work on the physiological effect of bordeaux mixture on the sprayed plants. As has been noted a number of times in earlier bulletins⁴, bordeaux mixture appears to serve two purposes, namely: (1) As a fungicide, preventing early and late blights, (2) As a stimulant to the plant, causing it to produce a larger amount of starch. The first of these effects is well recognized and has been proved beyond question. The second effect, how-

¹ Wortmann, Ueber die sogennante, "Stippen" des Aepfel. Landw. Jahrb. 21, pp. 663-675 (1892). Bschocke, Landw. Jahrb. d. Schweiz. 11, p. 192 (1897).

² N. H. Sta. Rpts. 19 and 20, pp. 332-386 (1907-1908).

³ Vt. Sta. Rpt. 12, pp. 159-164 (1898).

⁴ Vt. Sta. Bul. 159 (1911) and others preceding it.

ever, is less clearly determined. The experiments herein cited attempt to throw light on some of the obscure points as to bordeaux stimulation.

Under the conditions of potato growth around Burlington—and the same results have been obtained at a number of other places, notably in New York—there seems to be no question that sprayed potato plants yield more tubers than do unsprayed plants even in years when no fungus diseases occur. It has not been definitely ascertained, however, whether this is due to:

1. A daily increase in the amount of starch produced within the sprayed plants on account of the application of the copper mixture; or

2. An increase in amount of starch brought about by the lengthened life of the plant during September; unbordeauxed plants dying ten days to two weeks earlier as a rule than unsprayed ones.

The same problem was under survey last year¹; and the work of the current year has been in the main an attempt to repeat and to verify the results then secured. The method used to determine whether an actual daily increase resulted from the application of bordeaux mixture to the foliage was to dig the potatoes at various times during the summer and early fall and weigh the tubers from bordeauxed and unbordeauxed rows. Last year's results indicated that the bordeauxed plants stored daily more starch than did those not thus treated. The first harvest (September 2) yielded 194.8 bushels per acre from the sprayed plots and 170 bushels from the unsprayed; the second (September 16), 299.8 bushels from the sprayed area and 210.8 bushels from the control; the final harvest (October 20) showed 240.3 bushels per acre from the sprayed plants and only 202.1 bushels from the unsprayed. At the time when each harvest was made the sprayed plants had produced more pounds of starch and more bushels of potatoes per acre than had the unsprayed plants, regardless of the lengthened life of the plants themselves.

¹ Vt. Sta. Bul. 159 (1911).

Copper compounds other than the usual bordeaux mixture were also used on some of the plots. These mixtures were a bordeaux in which part of the copper sulphate was replaced by iron sulphate, Pickering's bordeaux mixture, Cucasa, and a soap-silver nitrate solution.

The copper-iron sulphate mixture contained 4 pounds iron sulphate, 2 pounds copper sulphate, 6 pounds lime and 50 gallons of water. This had been applied during the two preceding years and found almost to equal bordeaux in its effect on the plants. It was thought that this season might give an opportunity for testing its physiological effects in addition to its fungicidal properties.

Pickering's bordeaux mixture is a compound recommended by the Woburn (England) Experiment Fruit Farm¹. It consists of the precipitate formed by the addition of a weak copper sulphate solution to a saturated solution of lime-water. The advantages claimed for it are: (1) It is immediately fungicidal, whereas ordinary bordeaux requires some days before it is effective. (2) It does not clog the spray nozzles. (3) It does not scorch foliage as easily as do those mixtures made from the milk of lime. Pickering's bordeaux was used on the present experiment because it practically eliminated the question of lime and of shading. Some investigators have claimed that the effects are due in the ordinary mixture to the lime rather than to the copper, while others believe that bordeaux shades the leaves enough to make a difference between the treated and untreated plants.

"Cucasa" is a copper saccharate spray mixture put up in cartons by the Dr. L. C. Marquart Chemical Works, at Beul on the Rhine, Germany. Each carton contained two packages, a blue and a white one. The blue package, which weighs about 2½ pounds (1130 grams), contains, according to the analysis

¹ Woburn Exp. Fruit Farm Rpt. 116 (1910).

of an Austrian experiment station¹, 51.6 percent of copper sulphate and 41 percent of cane sugar. The white package, which weighs about a pound (420 grams) contains, according to the same analysis, 83.2 percent calcium hydroxide and 16 percent calcium oxide. The blue package is dissolved in about ten gallons of water and the white package is then stirred in. The result is a blue precipitate which, after a few minutes stirring, goes into solution, forming a dark blue liquid. It is claimed by the inventor that this dark blue liquid (a copper saccharate) is much more efficacious in the prevention of disease than is bordeaux prepared in the ordinary way. It was, however, with the intention of ascertaining its effect on the sprayed plants rather than its fungicidal properties that one plot was treated with this mixture. It presents the advantage of containing no free lime and of producing a minimum of shading, while getting the copper on the plant.

Vermorel and Dantony² have recommended a mixture of silver nitrate and soap for spraying grape vines. They claim that it produces the same dark green color in the leaves as does the copper compounds. This naturally suggested that an increased yield might be expected if a similar effect resulted on the potato foliage. The compound was made with about 15 grains of silver nitrate and 75 to 85 grains of soap to the gallon.

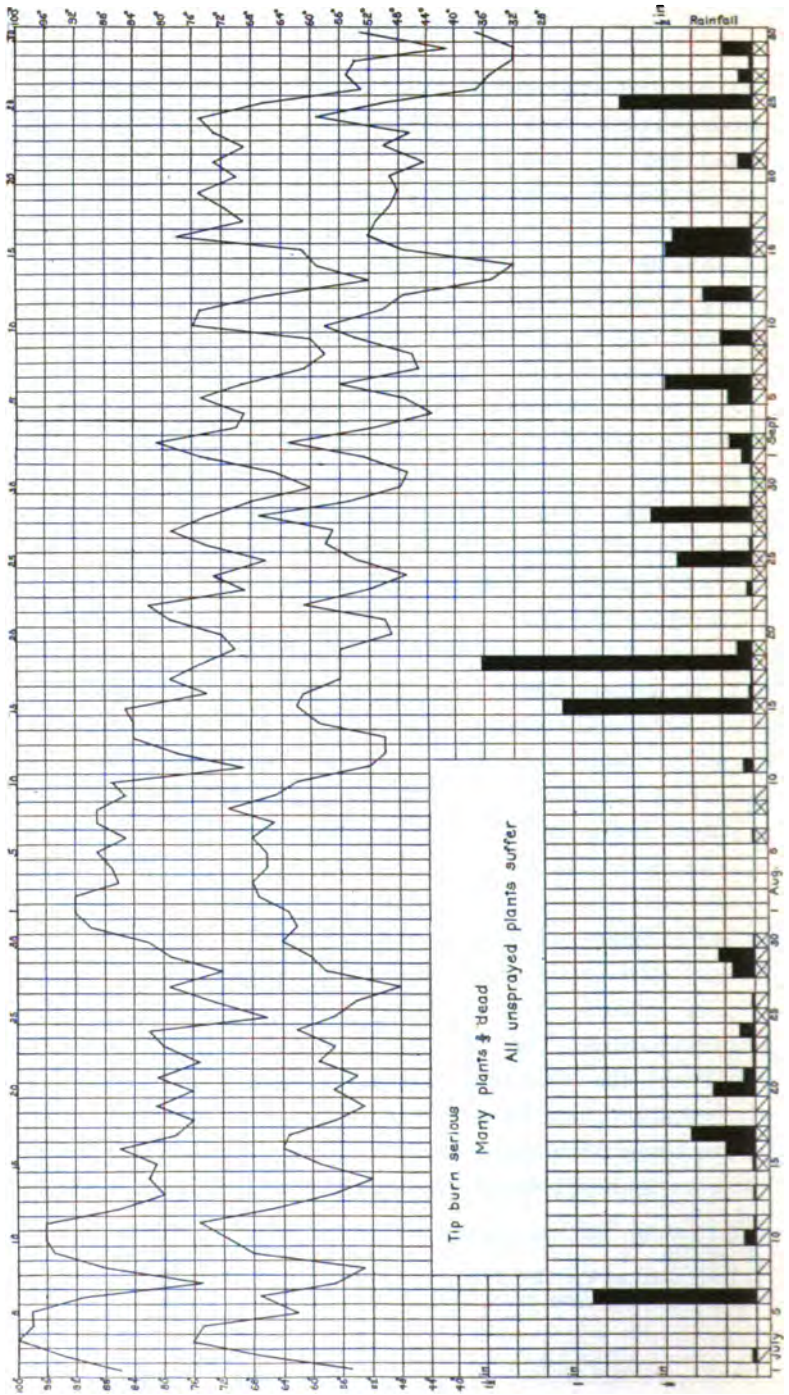
The ordinary 5-5-50 bordeaux mixture was used. One half pound of paris green was added to every fifty gallons of the bordeaux mixture, Pickering's bordeaux and the copper-iron sulphate mixture. The control plants and those on the plots sprayed with the other mixtures were dusted regularly with dry paris green and lime (1:20).

The Green Mountain potatoes which were used were planted on May 15, and sprayings were made July 13, July 31, August 12

¹ *Zeitschrift für das landwirtschaftliche versuchswesen in Oesterreich* (1910).

² *Prof. Agr. et Vit* (Ed. l'Est. Centre) 31, No. 32, pp. 168, 169 (1910); *Abstr. in Exp. Sta. Rcd.* 24, p. 51 (1911).

Year 1911



and August 24. The season was an excellent one for conducting experiments on the effect of the spray mixtures on the treated plants in view of the fact that no potato diseases appeared to introduce disturbing factors. Tip-burn, especially on the unsprayed plants, was very common after the 5th of August.

The first digging was made August 30. It consisted of a plot on which the plants had been sprayed with 5-5-50 bordeaux mixture and a control plot.

	Marketable tubers per acre	Small tubers per acre	Total tubers per acre
Sprayed with bordeaux mixture.....	41.1 bu.	12.5 bu.	53.6 bu.
Control	22.7 "	7.8 "	30.5 "

At this time the unsprayed plants had already suffered badly from the tip-burn and the tops only weighed a half pound each as compared to one pound and seven ounces for the sprayed.

The second digging was made September 13 when a sprayed plot and an unsprayed one were dug with the following results:

	Marketable tubers per acre	Small tubers per acre	Total tubers per acre
Sprayed with bordeaux mixture.....	85.3 bu.	10.7 bu.	97.0 bu.
Control	46.0 "	8.1 "	54.9 "

The rains of late August and the early part of September had checked the tip-burn and the weight of the tops was about the same as on September 13. The average weight of a sprayed top now was 1.21 pounds and of the unsprayed 0.52 pounds.

The third and final harvest was made on October 9, all the foliage being dead at this time. The yields from the various acre plots were as follows:

	Marketable tubers per acre	Small tubers per acre	Total tubers per acre
Sprayed with bordeaux mixture.....	144.2 bu.	12.7 bu.	156.9 bu.
Sprayed with iron and copper sulphate	113.3 "	10.8 "	124.1 "
Sprayed with Pickering's bordeaux..	109.9 "	9.1 "	119.0 "
Sprayed with Cucasa	139.7 "	10.8 "	146.5 "
Sprayed with silver nitrate and soap	58.4 "	11.4 "	69.8 "
Control	61.8 "	13.9 "	75.7 "

The year was an unfavorable one for potato development, especially on the light sandy soil which was used. This circumstance will account for the very light yields. No fungus or bacterial disease was present, and the results are without question due to the different spraying mixtures the plants received.

In every case where copper was used the plots showed an increase over the unsprayed plots, or those treated with silver-nitrate-soap mixture. The silver-nitrate-soap mixture in fact seemed to work slight injury. The plots sprayed with the mixture of iron and copper sulphate showed, as in previous years, that this compound is a close rival to the ordinary bordeaux. The yield from the "Cucasa" plot was almost as great as that afforded by the bordeauxed plants. The foliage treated with "Cucasa" did not show the marked dark-green color that is so characteristic of bordeauxed leaves, but the yield was consistently, row for row, larger than that from the check. The effect of the Pickering's bordeaux could also be seen in an increased yield, but it was not as marked an increase as from the 5-5-50 bordeaux. There is not nearly as much copper present in a gallon of this mixture as in any of the other mixtures applied. In fact, taking these figures at their face value, it would seem that the amount of increase is directly proportional to the amount of copper sulphate used. The surprising feature, however, was that the "Cucasa" should have afforded such a result without producing any marked change in the appearance of the foliage.

In general the results tend to confirm the deduction made as a result of last year's work, viz.: that the application of bordeaux mixture brings about a daily increase in the amount of starch produced per plant. This increase was much greater this year than last. Whether this increase would be as great on a heavy clay soil, or under the conditions of a large amount of rainfall, is a question still unanswered. From information received from one potato grower who sprays thor-

oughly, but whose land is much heavier than is the loose sandy soil around Burlington, it would seem that the results are not so well marked. On light soil, however, it pays to spray whether the year is a dry or wet one. If it is dry, the bordeaux prevents tip-burn with the resulting early death of the plants, and increases the amount of starch formed daily. If it is wet, the bordeaux effectually prevents the early and late blights with the resulting tuber rot induced by the latter malady.

A word might be added regarding the "Cucasa," the German mixture that produced such favorable results. The principal advantage it possesses is that it is convenient, because it is always ready. It can be bought in packages of various sizes and might be of service where only a small amount of spraying is to be done. The cost, however, prohibits its use in large field operations as the price, not delivered, is three times that of the materials of the ordinary mixture. A further disadvantage attending its use is that it will not keep any length of time.

The results attained at this station during twenty-one seasons' potato spraying are displayed on the next page. These may be best seen in the form of a table in which only the yields from the plots sprayed with bordeaux mixture are compared with control plots that have been left unsprayed.

GAINS FROM THE USE OF BORDEAUX MIXTURE ON LATE POTATOES

Planted	Sprayed	Yield per acre		Gain per acre		Prevalence of late blight
		Sprayed	Not sprayed			
White Star,		bu.	bu.	bu.	%	
May —, 1891	Aug. 26, Sept. 8,	313	248	65	26	some
May 20, 1892	Aug. 1, 16, 29,	291	99	192	194	much
May 20, 1893	Aug. 1, 16, 29,	338	114	224	196	much
Apr. 26, 1894	June 16, July 17, Aug. 30,	323	251	72	29	none
May 20, 1895	July 25, Aug. 13, 31,	389	219	170	78	rot
Polaris,						
May 15, 1896	Aug. 7, 21	325	267	68	26	none
June 1, 1897	July 27, Aug. 17, 28,	151	80	71	89	some
White Star,						
May 10, 1898	July 21, Aug. 10,	238	112	126	112	little
Average,						
3 varieties,						
May 18, 1899	July 26, Aug. 17, Sept. 8,	229	161	68	42	little
Delaware,						
May 23, 1900	Aug. 4, 23,	285	225	60	27	rot
May 25, 1901	July 20, Aug. 21,	170	54	116	215	much
May 15, 1902	Aug. 1, 20,	298	164	134	82	severe
Green Mountain,						
May 1, 1903	Aug. 10,	361	237	124	52	severe
Delaware,						
May 25, 1904	Aug. 1, Sept. 1,	327	193	134	69	some
May 15, 1905	Aug. 2, 21,	382	221	161	73	severe
Green Mountain,						
May 27, 1906	Aug. 13, 22,	133	101	32	32	some
May 1, 1907	July 16, 25, Aug. 8, 22,	171	63	108	175	little
May 15, 1908	June 26, July 9, Aug. 6, 26,	156	65	91	140	none
May 28, 1909	July 12, 23, Aug. 6, 27,	243	188	55	29	none
May 9, 1910	July 11, 27, Aug. 15, 23, 30,	240	202	38	18	none
May 15, 1911	July 13, 31, Aug. 12, 24,	156	75	81	108	none
Average for 21 years,		263	159	104	65	

Particular attention is to be called in the table on the opposite page to the results attained during the past four years *during which time there has been absolutely no blight*; but *the sprayed potatoes yielded an average of 66 bushels per acre, or 50 percent more than did the unsprayed*. Applying bordeaux mixture in these years might well be termed "spraying for drought."

Query: If in years when no blight occurs a crop is increased one-half, at a cost of, perhaps, one twenty-fourth; if in years when blight occurs, a crop is increased 27 to 215 percent at a relatively small outlay; why do not more potato growers spray? "If to do were as easy as to know what were good to do, chapels had been churches and poor men's cottages princes' palaces."—*Merchant of Venice* I, 2.



UNIVERSITY OF VERMONT
AND STATE AGRICULTURAL COLLEGE

VERMONT AGRICULTURAL
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Mendelian Inheritance in the Carnation

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*In cooperation with Bu. An. Ind., U. S. Dept. Agr.

BULLETIN 163: MENDELIAN INHERITANCE IN THE CARNATION

By WM. STUART

Note.—The completion of the studies reported in this bulletin was made possible through the courtesy of the Chief and of the Horticulturist of the Bureau of Plant Industry of the Department of Agriculture, who generously allowed the former station horticulturist, the author of this bulletin, time to pursue his studies in carnation breeding, and facilities wherewith to work, after he had entered the office of horticultural investigations in that Bureau.—J. L. HILLS, Director.

During the past decade plant breeding has commanded, as never before, the careful attention of scientific as well as practical students of genetics. The reasons for this increased interest are many and varied. Such fascinating and immensely important conceptions as the Mendelian theory of inheritance, the de Vries mutation theory, and the theory of elementary species in pure varieties, strains, or races, have stimulated scientific inquiry. Then, too, there is an increasing demand for new varieties, better adapted to varying locations and environments, than those now existing. Drouth resistance, heat resistance, cold resistance, disease resistance and a host of other desirable attributes are sought. Because of these varied demands much work, investigational and practical, has been accomplished.

MENDEL'S LAW

While the Mendelian theory of inheritance is now as familiar to the student of genetics as are "Mother Goose" stories to the small child, the brief interpretation of Mendel's law which follows may serve to enable those not entirely familiar with this theory the better to understand the subject matter which is to follow. In 1900 Hugo de Vries re-discovered an old paper by Gregor Mendel, entitled "Experiments in Plant Hybridization."¹ This paper was presented before a scientific society in Brunn, Austria, in February and March, 1865. It contained a detailed account of carefully conducted investigations with the garden pea, in which the inheritance of certain definite characters was noted. A perusal of Mendel's paper at once impresses the reader with the painstaking care with which these investigations were undertaken. Only such varieties of the garden pea were selected

¹Mendel, G. "Versuch über Pflanzen-Hybriden." Verh. naturf. Ver. in Brunn, Abhandlungen IV, 1865.

for the work as had been shown by two or more seasons' culture to possess the ability of reproducing themselves absolutely true from seed, and to exhibit opposing pairs of characters. Altogether Mendel worked with seven opposing pairs of unit characters. For the purposes of the present discussion one pair, namely, round and wrinkled seed, will suffice to illustrate the method pursued. These being well-defined characters were easy to study and to interpret in the resulting progeny. Mendel found that the hybrids of this cross, or the F_1 generation, consisted solely of round seeds. He, therefore, called the round-seeded variety the dominant type. In the F_2 generation from self-fertilized plants he found that there was a splitting up of these characters in a fairly uniform and definite ratio. On an average it was found that the plants produced about 75 percent of round and 25 percent of wrinkled seeds. The wrinkled pea was then said to be recessive to the round. In the subsequent generation produced from these peas, the wrinkled seeds produced all wrinkled seeds, while 25 percent of round seed produced plants which gave all round seeds, and the remaining 50 percent produced both round and wrinkled progeny in the same relative proportion as in the preceding generation. From these data Mendel formulated the numerical ratio for the F_2 generation of 1 : 2 : 1; or, 25 percent dominants, 50 percent dominant-recessives and 25 percent recessives.

In order to simplify further discussions along this line the algebraic expression $R + 2 R_w + R$ may be used to represent the numerical values of the hybrids. (R = round and W = wrinkled). Then we have as the result of this cross $R \times W = RW$. But as W is the recessive character in this case, it does not find expression in the hybrid; hence it is usually written R_w . An expression of this sort always indicates that the seed contains two characters, one of which is unexpressed. Still further to facilitate clarity of understanding, it seems desirable to define a few words which may be unfamiliar to those not conversant with the terminology of plant breeding. The term "gamete," is used



PLATE I. A. View of seedling carnations, 1907-08.



PLATE I. B. Seedling carnations in Station trial grounds, 1907-08.



PLATE II. A. Seedling carnation breeding bench Arlington Farm greenhouse, 1910-11.



a a' b b' c c'
PLATE II. B. Bud and flower of typical single, commercial and double carnations.



PLATE III. A. Undesirable types of buds. Only the three on the right are regarded as true doubles.



PLATE III. B. Commercials and "doubles" selected for analysis. Types A, B, C are "commercials," D, E, "doubles."



PLATE IV. A. Petals of commercial type A. (Plate III-B).



PLATE IV. B. Petals of commercial type B. (Plate III-B).

by the biologist to denote the sexual cells of a plant. The gamete is supposed to contain all of the heritable characters of a plant or animal. The resultant fusion of a female gamete and a male gamete forms what is known as a "zygote." If the fusing gametes are of similar constitution, that is to say, if they possess identical unit characters, as in the case of pure strains of plants, the resulting zygote is called a "homozygote," because it possesses a homogenous constitution. On the other hand, if gametes of unlike constitution fuse with each other, the resulting union is called a "heterozygote," because it contains unlike and opposing characters. According to these definitions Rw is a heterozygote. Each ovule and pollen grain, therefore, developed in plants produced from the Rw seed would theoretically contain both the R and W characters, and, according to the law of chance, would combine in about equal proportions. This may be thus illustrated:

Ovule Pollen

$$\begin{array}{c} R \\ W \end{array} \quad \begin{array}{c} R \\ W \end{array} = R + 2\,Rw + W \text{ or the expression } 1 : 2 : 1.$$

It is important, however, to remember that Mendelian inheritance only gives such an expression as the above, when plants are employed which are gametically pure, that is to say, plants in which two opposing or contrasting characters do not exist in the same gamete. Likewise plants must be selected in which recognizable contrasting characters already exist.

PREVIOUS OBSERVATIONS ON INHERITANCE

While to Mendel must undoubtedly be given the credit for having demonstrated the inheritance of unit characters in a definite numerical ratio by the offspring of crosses made between plants possessing opposing characters, it by no means follows that the phenomena he observed had not been noted long prior to his publication. The following quotation from Knight¹ abundantly

¹Knight, T. A. "Experiments on the Fecundation of Vegetables." *Philo. Trans. Roy. Soc.* for 1799, p. 197.

indicates that he was familiar with the splitting up of the characters in the F_2 generation of hybrids. "When I introduced the farina of a purple blossom (of the garden pea) into a white one, the whole of the seeds in the succeeding year became colored; but, when I endeavored to discharge this color by reversing the process, a part only of them afforded plants with white blossoms, this part occupying one end of the pod and being at other times irregularly intermixed with those which, when sown, retained their color." Goss¹ reported in October, 1822, the results of his observations on color variation in hybridized garden peas. The following brief quotation indicates the nature of this work. "In the summer of 1820 I deprived some blossoms of the Prolific Blue of their stamina, and the next day applied the pollen of a dwarf pea; and of which impregnation I obtained three pods of seeds. Towards the end of the following summer I was surprised to find that some of the seeds had produced some pods with all blue, some with all white, and many with both blue and white peas in the same pod. Last spring I separated all the blue peas from the white and sowed each color in separate rows, and I now find that the blue produce only blue, while the white seeds yield some pods with all white and some with both blue and white pods intermingled."

It is evident that Goss had observed that the white color was dominant to the blue, and that there was a splitting up of the progeny into the parental and the heterozygous types; but both he and Knight failed to observe the numerical ratio in which the parental forms reappeared.

OBSERVATIONS ON THE CARNATION

The writer received his first suggestion regarding the possibility of Mendelian inheritance in the carnation through the presentation of a brief paper entitled "Carnation Seedlings and Mendel's Law" by Norton² of the United States Department of

¹Goss, J. "On the Variation in the Color of Peas occasioned by Cross Impregnation." *Trans. Hort. Soc., London*, 5: pp. 234-236, (1824).

²Norton, J. B. "Carnation Seedlings and Mendel's Law." *Proc. Soc. Hort. Sci.*, p. 105, (1905).

Agriculture, based upon data secured from some 300 seedling plants relative to the proportion of plants bearing single and double flowers. It has long been well recognized that the cultivated varieties of the carnation (*Dianthus caryophyllus*) do not reproduce themselves true from seed, and, furthermore, that a considerable proportion of single and double flowers, commonly called "bullheads," occur in all seedling plants. So far as known to the writer, Norton was the first to suggest the possibility that commercial doubles were simply the heterozygous expression of a fusion of gametes containing single and double unit characters. In support of this assumption it was predicted that if the single flower was crossed with pollen from the "bullhead" or double, the resulting progeny would all produce intermediate commercial or semi-double flowers. Further investigations along this line¹ were reported in 1907. Only one plant from 250 seedlings, the progeny from several crosses between single and double flowers, produced single flowers. No crosses were reported between singles and singles, or between singles and the commercial or semi-double flowers.

STATION INVESTIGATIONS

In order further to substantiate or disprove Norton's theory, the writer, while engaged in the pursuit of other studies on the carnation in the station greenhouse, notably that on the "Seasonal Influence of Carnation Crossing Relative to Seed Production" previously reported,² carried on some work along this line during the winters of 1907-08 and 1908-09. On assembling these data toward the close of the summer of 1909, it was decided that the evidence secured was too meager to warrant publication. The severance of the writer's connection with the station in the summer of 1909, brought the investigation to an abrupt termination for the time being. In the spring of 1910 arrangements were made with the United States Department of Agriculture

¹Norton, J. B. "Heredity in Carnation Seedlings"; Amer. Breed. Assn. Rpt. 3, p. 81, (1907).

²Vt. Sta. Rpt. 20: pp. 355-358, (1908).

whereby the writer was permitted to complete his studies. Through the generosity of the H. Dorner Sons Co. of Lafayette, Indiana, single and double flowering seedling plants were secured in October, 1910, which served as a basis for the continuation of the work during 1910-1911.

TECHNIQUE

No attempt was made in the crosses of 1907-08, and 1908-09 to protect flowers from accidental pollination through bees or other agencies. In 1910-11, however, the seed parent was inclosed in a cheesecloth sack which was replaced after pollination and allowed to remain until danger from cross pollination was past. The pollen was usually secured by removing the stamens with a finely pointed pair of forceps; and these were either transferred to a glass slide from which they were used as wanted, or else the stamen was carried directly to the flower to be pollinated, and, without releasing it, the ruptured anther with its attached pollen grains was brought in direct contact with the stigma. From two to four days usually elapsed between emasculation and pollination.

The crosses were all recorded in the order of the seed parent. Thus the phrase, "single x double" indicates that the single flower was the seed parent. The seeds were usually sown in March and grown in the greenhouse until they could be planted in the field. Most of the plants flowered in the field.

1907-08 EXPERIMENTS

The lines of inquiry pursued in 1907-08 had for their object the determining of the relative effect of the following crossing upon the resultant progeny:

Single x single, commercial x single, single x double, commercial x commercial, double x double.

It was soon found that with the available material at hand which showed abortive ovules or imperfect pistils, the double flowers could not be made to produce seed. This made it impossible to determine the purity of the double except as evidenced in the progeny from single crossed with double.

PROGENY OF 1907-08 CROSSES

Single x Single. The data obtained from crossing single flowers with pollen from singles, as given in table I, page 58, shows that an average of 19.2 seeds were produced per capsule from the eleven successful crosses recorded. The number of seeds were found to vary in the individual capsule from 2 to 52. Only 41.7 percent of the 211 seeds secured reached the field planting stage, all but two of which produced flowers, and, what is more important, all were single flowers. This result seems to justify the assumption that the singles are pure recessives.

Commercial x Single. The data obtained from crossing commercial flowers with pollen from singles which is presented in table II, p. 591, shows that from the six crosses recorded an average of 17.8 seeds were produced per capsule, the range of variation being from 6 to 29. Forty-one plants, or 38.3 percent, were grown from the 107 seeds, all of which reached the flowering stage. Twenty-one of these produced single flowers and 20 commercials. While these numbers are altogether too small to warrant definite conclusions, the results are certainly suggestive. Mendel's law requires that there should be 50 percent of each, whereas the data just presented gives 51.2 percent single and 48.8 percent commercials. No closer approximation could be obtained with the number of plants employed. The cross is graphically expressed in the following diagram. Assuming that the commercial flower contains the unit character of single and double, we have

$$\begin{array}{ccccc}
 \text{Ovule} & \text{Pollen} & & & \\
 \begin{array}{c} D \\ S \end{array} & \begin{array}{c} S \end{array} & = & Ds + S
 \end{array}$$

TABLE I
Progeny of single flowers crossed with singles, 1907-08.

No. of cross	Parentage	Date of		Number of			Character of flowers	
		Pollination	Removal of capsule	Seeds	Planted in field	Flowered	Single	Double
3-c-3	13-b x 13-b	Oct. 25, '07	Jan. 3, '08	2	2	2	2	..
4-c-3	65-b x 44-b	" 27, "	" 3, "	20	9	9	9	..
5-c-3	44-b x 97-b	" 27, "	" 10, "	33	18	18	18	..
6-c-3	101-b x 44-b	" 27, "	" 3, "	4	1	1	1	..
10-c-3	109-b x 109-b	" 28, "	" 5, "	26	7	7	7	..
12-c-3	1-b x 3-b	Nov. 1, "	" 3, "	52	20	20	20	..
13-c-3	86-b x 13-b	" 7, "	" 3, "	5	2	1	1	..
14-c-3	109-b x 13-b	" 7, "	" 3, "	13	3	3	3	..
19-c-3	58-b x 13-b	" 12, "	" 3, "	16	7	7	7	..
20-c-3	109-b x 13-b	" 13, "	" 3, "	26	9	9	9	..
22-c-3	109-b x 26-b	" 16, "	" 3, "	14	10	9	9	..
Total crosses = 11.....				211	88	86	86	..
Average per cross.....				19.2	8	7.8	..	..

TABLE II
Progeny of commercial flowers crossed with singles, 1907-08.

No. of cross	Parentage	Date of		Number of			Character of flowers		
		Pollination	Removal of capsule	Seeds	Planted in field	Flowered	Single	Commercial	Double
1-c-4	Flamingo x 13-b	Oct. 28, '07	Jan. 3, '08	6	2	2	1	1	..
2-c-4	37-b x 13-b	Nov. 7, "	" 3, "	25	4	4	3	1	..
3-c-4	117-b x 109-b	" 7, "	" 3, "	13	7	7	2	5	..
8-c-4	Flamingo x 13-b	" 16, "	" 3, "	22	7	7	3	4	..
9-c-4	71-b x 13-b	" 16, "	" 3, "	29	19	19	10	9	..
12-c-4	Eclipse x 13-b	" 22, "	" 23, "	12	2	2	2	..	..
Total crosses = 6				107	41	41	21	20	..
Average per cross				17.8	6.8	6.8	..	..	..

Commercial x Commercial. The twenty-three crosses between commercial types of flowers recorded in table III, on the opposiet page, yielded 591 seeds, or an average of 25.7 seeds per capsule.

The range of variation was from 6 to 43 seeds. Of this number 376 germinated and 270 produced plants that grew, all but two of which flowered, or respectively 63.6, 45.7, and 44 percents. Of the 260 plants that flowered, 62 produced single flowers and 198 produced commercial and double flowering plants. As no attempt was made at the time of taking the data to distinguish between the commercial and true doubles, it is not possible to arrive at any conclusion regarding the relative percentage of each of these two types except by analogy from the percentage of singles.

The theoretical percentage of single, commercial, and double flowering plants from a cross such as that under consideration should be 25 percent double, 50 percent commercial, and 25 percent single. The cross may be expressed as follows:

$$\begin{array}{cc} \text{Ovule} & \text{Pollen} \\ \begin{array}{c} D \\ S \end{array} & \begin{array}{c} D \\ S \end{array} = D + 2 Ds + S \end{array}$$

The figures actually obtained were 23.8 percent single and 76.2 percent commercial and double. These figures closely approximate the expected ratio.

Single x Double. The eight recorded crosses between single and double flowering plants which are presented in table IV, p. 62, afforded an average of 32 seeds per capsule, or a total of 256 seeds. From this number, 147 plants were raised, and all but one produced flowers. The reader's attention is directed to the relatively larger percentage of seeds and of flowering plants which were obtained from the single-double combination than from any other. This seems to indicate that the progeny of such crosses is relatively more productive and vigorous. Of the 146 plants that flowered, 134 produced commercial types and 12 were noted as double. In this connection it should be said that at the time these notes were taken, any plant producing a large, but

TABLE III
Progeny of commercial flowers crossed with commercials, 1907-08.

No. of cross	Parentage	Date of		Seeds	Number of		Plants flowered	Character of flowers	
		Pollination	Removal of capsule		Germi- nated	Plants grew		Single	Double*
1-c	Flamingo x 37-b	Oct. 28, '07	Jan. 3, '08	37	18	10	9	..	9
2-c	80-b x 45-b	" 31, "	" 3, "	43	43	35	34	8	26
3-c	Flamingo x 37-b	Nov. 1, "	" 3, "	37	22	19	18	5	13
4-c	" x 37-b	" 1, "	" 3, "	13	9	5	4	1	3
5-c	" x 37-b	" 1, "	" 3, "	43	26	19	17	6	11
7-c	" x 37-b	" 5, "	" 3, "	33	26	25	24	13	11
8-c	" x 37-b	" 12, "	Feb. 3, "	15	13	6	6	2	4
9-c	" x 37-b	" 12, "	" 3, "	38	28	19	19	1	18
10-c	45-b x Belle	" 16, "	Jan. 23, "	21	17	7	7	1	6
11-c	Belle x 32	" 16, "	" 3, "	13	10	10	10	4	6
12-c	Flamingo x 37-b	" 16, "	Feb. 3, "	20	11	9	9	1	8
13-c	" x 37-b	" 16, "	Jan. 3, "	21	9	6	3	..	3
14-c	" x 37-b	" 16, "	" 3, "	25	9	6	6	..	6
15-c	" x Rbt. Craig	" 16, "	" 28, "	45	16	11	11	3	8
17-c	80-b x 45-b	" 16, "	" 3, "	27	19	9	9	1	8
18-c	37-b x Rbt. Craig	" 18, "	Feb. 3, "	18	6	3	3	..	3
19-c	32 x 75-b	" 18, "	Jan. 23, "	10	7	6	6	..	6
20-c	45-b x 75-b	" 18, "	" 23, "	10	10	8	8	2	6
21-c	Rbt. Craig x 37-b	" 22, "	" 23, "	10	9	6	6	2	4
22-c	" x 37-b	" 22, "	" 28, "	18	16	15	15	5	10
23-c	Flamingo x Rbt. Craig	" 22, "	Feb. 3, "	31	16	9	9	2	7
24-c	" x "	" 22, "	Jan. 28, "	39	28	25	25	4	21
25-c	" x "	" 23, "	" 3, "	24	8	2	2	1	1
Total crosses = 23				591	376	270	260	62	198
Average per cross =				25.7	16.3	11.7	11.3	..	..

*No attempt was made to distinguish between commercials and true doubles.

TABLE IV
Progeny of single flowers crossed with doubles, 1907-08.

No. of cross	Parentage	Date of		Removal of capsule	Number of			Character of flowers		
		Pollination			Seeds	Planted in field	Flowered	Single	Commer- cial	Double
1-c-2	1-b x 63-b	Oct. 25, '07		Jan. 3, '08	20	18	18	..	14	4
5-c-2	53-b x 109-b	" 25, "		Feb. 6, "	40	27	27	..	27	0
7-c-2	69-b x 63-b	" 27, "		Jan. 10, "	42	24	23	..	22	1
8-c-2	69-b x 63-b	" 27, "		" 10, "	27	12	12	..	11	1
9-c-2	1-b x 63-b	" 27, "		" 3, "	57	21	21	..	20	1
10-c-2	13-b x 63-b	" 27, "		" 3, "	31	19	19	..	16	3
11-c-2	26-b x 63-b	" 28, "		" 3, "	34	21	21	..	19	2
12-c-2	109-b x 63-b	" 31, "		" 3, "	5	5	5	..	5	0
Total of crosses = 8					256	147	146	..	134	12
Average per cross					32	18.4	18.3	..	..	..

vertically short, bud with a bursting calyx, was assumed to be a "bullhead" (double). More recently, however, a careful examination of this type of flower leads the writer to the conclusion that this condition does not necessarily indicate that the flower is a true double. It is, therefore, quite possible that the twelve doubles noted may after all have been simply abnormal blooms of the commercial type. The data, to have been strictly in accordance with Mendel's law, should have given all commercial flowers. The expression of such a cross is written thus $D \times S = Ds$.

ARLINGTON FARM INVESTIGATIONS, 1910-11

In view of the fact that the data secured from the 1907-08 crosses were considered too meager to justify publication, the work was continued another season.¹ Accordingly single and double flowering seedling plants were secured and crossings begun early in December, 1910, between singles with singles and singles with doubles. Eleven successful crosses were made between single flowering plants and thirty-six between the single and double.

Single x Single. The results secured from the eleven crosses above noted which are presented in table v, p. 64, show a total production of 364 seeds or an average of 33.1 seeds per capsule. The number of seeds per capsule varied from 11 to 46. Of this number 295, or 81 percent, germinated, and 269 plants, or 73.9 percent, reached the planting out stage; and all but one produced flowers. Every one of the 268 plants that bloomed was single flowered, a result fully substantiating the result attained in 1907-08 (table i, page 58).

Single x Double. In view of the fact that the single-double combination was a particularly crucial one, an effort was made to procure a larger number of crosses than in the previous work. The success of these crosses can best be attested by the data pre-

¹Conditions were so unfavorable and the seed parents so poor that no use is made in this bulletin of the considerable amount of data secured in 1908-09.

TABLE V
Progeny of single flowers crossed with singles, 1910-11.

No. of crosses	Percentage	Date of			Number of				Character of flowers		
		Emasculation	Pollination	Removal of capsule	Seeds	Germi- nated	Planted in field	Flow- ered	Single	Com- mercial	Double
4	34 x 27	Dec. 5, '10	Dec. 8, '10	Feb. 18, '11	46	45	45	45	45	..	..
5	45 x 42	" 8, "	" 14, "	" 18, "	11	11	10	10	10	..	..
6	43 x 42	" 5, "	" 14, "	" 18, "	34	25	23	23	23	..	..
7	21 x 42	" 5, "	" 14, "	" 16, "	13	8	8	8	8	..	..
8	27 x 44	" 8, "	" 16, "	" 18, "	47	38	32	32	32	..	..
9	9 x 21	" 5, "	" 14, "	" 18, "	35	28	22	22	22	..	..
10	9 x 45	" 5, "	" 14, "	" 18, "	37	33	29	29	29	..	..
11	20 x 50	" 21, "	" 21, "	" 18, "	25	21	18	18	18	..	..
12	87 x 22	" 21, "	" 29, "	Mar. 4, "	38	35	33	33	33	..	..
14	40 x 47	" 29, "	Jan. 4, '11	" 4, "	32	19	19	19	19	..	..
16	87 x 30	Jan. 6, '11	" 16, "	" 4, "	46*	31	30	29	29	..	..
Total number of crosses = 11					364	294	269	268	268	..	..
Average number seeds per cross.....					33.1	26.7	24.5	24.4	..	..	..

*Ten immature seeds.

TABLE VI Progeny of single flowers crossed with double flowers, 1910-11.

No. of cross	Percentage	Date of			Number of				Character of flowers		
		Emasculation	Pollination	Removal of capsule	Seeds	Germi- nated	Planted in field	Flow- ered	Single	Com- mercial	Double
111	39 x 69	Dec. 16, '10	Dec. 21, '10	Feb. 18, '11	55	17	16	16	1	15	..
112	46 x 69	" 16, "	" 22, "	" 18, "	42	39	39	39	..	39	..
113	30 x 69	" 19, "	" 24, "	" 18, "	50	44	44	43	..	43	..
114	40 x 69	" 19, "	" 26, "	Mar. 4, "	44	36	36	35	1	34	..
115	18 x 92	" 20, "	" 26, "	Feb. 18, "	145	107	105	105	..	105	..

116	33 x 56	" 24,	" 29,	" 18,	" 46	19	17	17
117	15 x 56	" 19,	" 29,	" 18,	" 30	18	18	18
119	10 x 93	" 20,	" 29,	" 18,	" 25	14	13	13
120	12 x 93	" 20,	" 29,	" 18,	" 52	27	22	22
121	39 x 54	" 26,	" 29,	Mar. 4,	" 37	33	31	31
122	37 x 73	" 26,	" 29,	Feb. 18,	" 33	14	11	11
123	34 x 76	" 22,	" 31,	Mar. 4,	" 37	25	24	24
124	26 x 76	" 29,	" 31,	Feb. 18,	" 7*	4	4	4
125	26 x 52	" 29,	" 31,	" 18,	" 4*	2	2	2
126	51 x 52	" 26,	" 31,	Mar. 4,	" 32	28	27	27
127	51 x 54	" 22,	" 31,	" 4,	" 42	37	34	34
128	47 x 69	" 29,	" 31,	" 4,	" 57	46	45	45
129	12 x 52	" 31,	Jan. 2, '11	" 4,	" 40	38	33	31
130	22 x 97	" 29,	" 2,	" 4,	" 58	48	46	46
131	33 x 56	" 26,	" 2,	" 4,	" 41	35	33	33
132	6 x 69	" 31,	" 4,	" 4,	" 20	15	15	15
133	6 x 69	" 31,	" 4,	" 4,	" 25	19	19	19
134	8 x 97	" 31,	" 4,	" 4,	" 78	4	3	3
135	23 x 82	Jan. 2, '11	" 4,	Feb. 18,	" 23*	11	8	8
136	33 x 82	Dec. 26, '10	" 4,	Mar. 4,	" 46	40	32	30
138	18 x 54	" 31,	" 5,	" 4,	" 72	39	33	1
140	27 x 54	" 31,	" 5,	" 4,	" 33	22	13	13
141	36 x 54	Jan. 2, '11	" 5,	" 4,	" 61	46	43	43
143	51 x 97	Dec. 26, '10	" 5,	" 4,	" 25	19	19	19
146	5 x 56	Pistillate	" 7,	" 4,	" 39	16	13	13
148	4 x 77	Jan. 2, '11	" 9,	" 4,	" 44	41	2	2
149	22 x 56	" 4,	" 9,	" 4,	" 57	43	38	37
153	30 x 92	" 5,	" 11,	" 4,	" 26†	8	8	8
155	8 x 2	" 9,	" 16,	" 10,	" 53	5	1	1
157	30 x 2	Pistillate	" 16,	" 10,	" 33	14	14	13
159	22 x 70	Jan. 16, '11	" 23,	" 10,	" 73	7	4	4
Total number crosses = 36					1585	981	865	854
Average number seeds per cross.					44	27.5	24	23.8
*Immature seeds. †Seeds not plump.								

• Immature seeds. † Seeds not plump.

sented in table VI, on the preceding pages, in which it will be noted that the thirty-six crosses produced 1,585 seeds or an average of 44 seeds per capsule, and that the number of seeds in the capsule varied from 4 to 145. Of this number 987, or 61.8 percent, germinated, and 865, or 54.6 percent, were set in the field. Seven plants succumbed to drouth; all of the rest produced flowers. Eight hundred fifty-four produced commercial flowers, and four single flowers. Theoretically there should have been no singles. The actual percentages secured are 99.51 percent commercial and 0.49 percent single. While the presence of four single flowering plants in a family of 858 individuals, or one out of each of four distinct crosses, tends to throw some discredit on the theory of gametic purity, it does not, in the opinion of the writer, necessarily disprove it. There is always the chance of a slight error on the part of the operator. The fine-meshed cheesecloth may not have excluded all of the smaller insects such as small flies, aphids and thrips. Furthermore it is quite possible that notwithstanding much precaution, all of the pollen grains were not removed from the forceps or glass slide when making the different crosses. An examination of the dates on which crosses III, IIIA, 138 and 157 were made shows that emasculation of single flowers, or crossing of the same with pollen from singles, occurred on the same dates as those on which the first three numbers were pollinated. This coincidence may or may not have a bearing on the appearance of these three single flowered plants. It would be quite within the range of possibility for a single pollen grain to have escaped the notice of the operator and to have been transferred along with that secured from the double flower. These suggestions as to a possible error in technique are not cited for the purpose of defending the Mendelian theory of inheritance, but are advanced as plausible explanations of the presence of these anomalies.

It seems worth while to assemble such of the data secured during the two seasons' work as appear most significant. This is presented in table VII, a careful study of which emphasizes the

TABLE VII
Comparison of data secured from the crosses between different types of flowers, Tables I-VI.

Nature of cross	No. crosses	Total seeds	Seeds		Average number plants flowered per cross	Total number of flowers			Per Cent		
			Average seeds per cross	Range of variation in cross		Single	Com-mercial	Double	Single	Com-mercial	Double
Single x Single.....	22	575	26.1	2-52	16.1	354	...	...	100	...	...
Commercial x Single.....	6	107	17.8	6-29	6.8	21	20	...	51.2	48.8	..
Commercial x Commercial...	23	591	16.3	10-45	11.3	62	198	...	23.8	76.2*	..
Single x Double	44	1841	41.8	4.14	22.8	4	988	.12†	.4	98.4	1.2†

*No attempt made to distinguish between commercial and double flowers when data was taken in 1908.

†This observation was made by the gardener, and it is quite possible that a badly bursted commercial flower was looked upon as a double.

greater prolificacy of the single-double crosses. An average of 22.8 plants were flowered from each capsule, whereas the nearest approach to the number in the other three crosses was that of the single x single combination which produced 11.3 flowering plants per cross. The commercial x commercial cross averaged 11.3 plants, while the commercial x single combination only produced 6.8 flowering plants per cross. The average numbers of seeds per capsule were approximately in the same ratio. A distinct gain in prolificacy in the single-double cross seems evident, and, furthermore, 100 percent of the seedlings produce flowers of the commercial type as against approximately 50 percent from the commercial x commercial crosses. It would appear, therefore, that the carnation breeder would do well to employ the single and double flowering plants as the parents of his crosses, rather than the usual commercial types.

The wide variation in the number of seeds produced between the different crosses of the same combination leads one to suspect that a careful study of these variations would demonstrate that certain plants are much more prolific than others. The data at hand, however, does not permit of safe generalization upon this point, owing to the comparatively few times the same individual plants were mated with like pollen parents. In crosses 124 and 125 of table VI, both capsules were produced on the same plant, but by different pollen parents. In each case, however, the number of seeds produced is extremely small, being 7 and 4 respectively. Crosses 115 and 138, in which both capsules were produced on plant 28, yielded 145 and 72 seeds respectively; and seed-parent 39 in crosses 111 and 121 produced 55 and 37 seeds respectively. The largest number of plants flowered from any one cross was 105 from cross 115.

These results would seem to indicate that a careful selection of prolific seed parents is desirable, and that when such parents are discovered, and their progeny have proved to be satisfactory, they should be propagated for the express purpose of serving as seed and pollen parents for the next year's work.



PLATE V. A. Petals of commercial type C. (Plate III-B).



PLATE V. B. Petals of double type D. (Plate III-B).

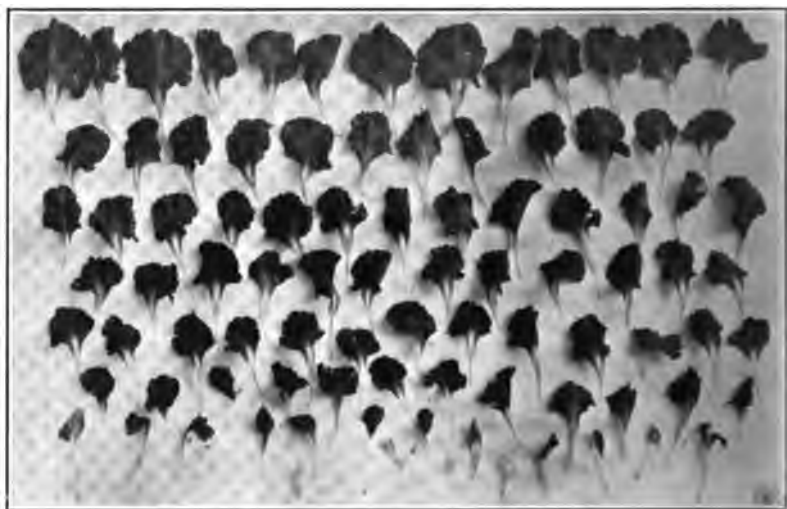
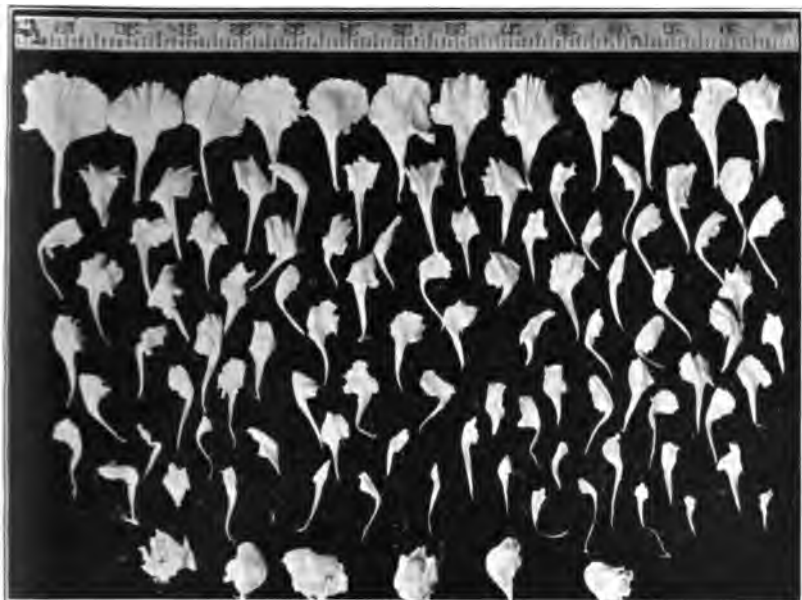


PLATE VI. A. Petals of double type E. (Plate III-B).



PLATE VI. B. An abnormally large double white carnation, F.



1 2 3 4 5 6
PLATE VII. A. Flower F, partially dissected. Note six adventitious buds.

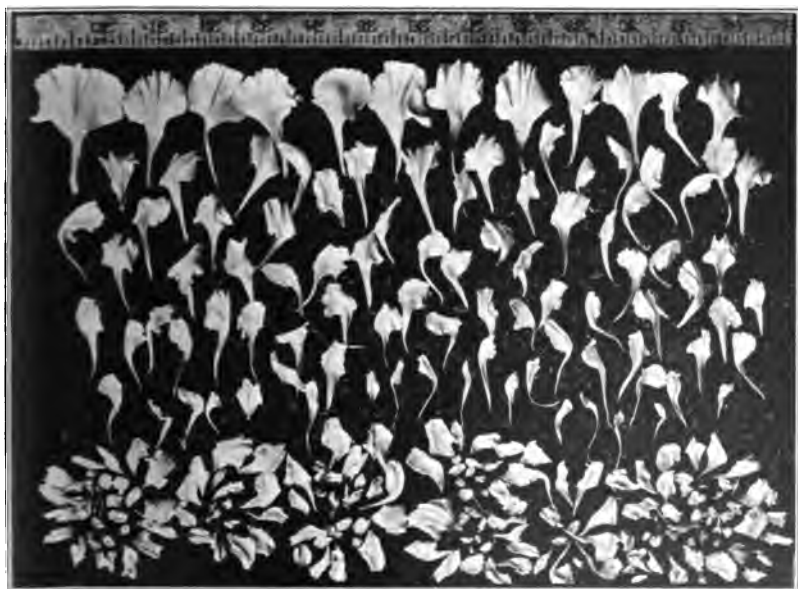


PLATE VII. B. The completely dissected flower F. Note parts of adventitious buds.



PLATE VIII. Types of "bursters" of Mrs. C. W. Ward carnation, showing adventitious bud opposite split calyx in the left hand blossom and an extra though abortive ovary in that on the right.



PLATE IX. A striking example of fasciation in a carnation petal.
PLATES II to VIII. From negatives furnished by the Bureau of Plant Industry of the United States Department of Agriculture.

A COMPARISON OF COMMERCIAL VERSUS DOUBLE FLOWERS

An examination of over 300 blooms of commercial and double types of flowers has brought to light many interesting facts concerning the relative number, size, and form of the petals. It was found that named commercial varieties varied from 28 to over 100 petals or petal-like organs per plant. Flowers of the Enchantress were found to range from 56 to 91 petals. In practically every instance Enchantress "bursters" showed a materially larger number of petals than did the ordinary type. Thus, for example, four perfect flowers contained 56, 58, 67 and 72 petals respectively, while four bursters contained 83, 86, 91 and 94 petals. This data has an interesting bearing on the phenomena of doubling as will be noted by the presentation of similar figures to those above. The analysis of several blooms of double or "bullhead" flowers gave the following number of petals, 87, 91, 110, 116, 125, 128, 140, 220, and 243. Three of these—91, 125, 243—may be studied in plates III, v, vi and vii, under E, D and F respectively. The reader's attention is particularly directed to figures A and B of flower F on plate vii. An examination of figure A shows the partially dissected F bloom, in which six adventitious buds are disclosed. These six buds are shown after dissection in figure B of the same plate.

It is now thought that these buds bear a significant relationship not only to the phenomena of doubling but to the frequent bursting of the calyx occurring in such full petaled commercial varieties as the Enchantress and Mrs. Ward. An examination of twelve Mrs. Ward bursters showed that all but two of them possessed one or more of these adventitious buds. It was also noted that these buds were generally located where the calyx had split. Flower c in plate III, figure B, is a Mrs. Ward burster. The dissected flower is shown in plate v, figure A. The group of small petals at the base of the photograph were from an extra bud, which possessed an ovary and pistils. These are shown just below the normal ovary and pistil. In this connection plate viii, figures A and B are of service. The same phenomena has

been noted in a few of the Enchantress, but the number of bursters examined is too limited as yet to warrant definite statement. No extra buds have been noted in bursters with a fewer number of petals than, say, from 30 to 50. It would seem from present observations that there is no well defined line of demarcation between a commercial and a double carnation, at least as determined by number of petals. The data secured from the Mrs. Ward and Enchantress carnations would lead one to believe that these varieties were on the border line between the commercial and the double type, and apparently some of them occasionally pass over the boundary usually supposed to be the upper limit of the commercial. When the petals of a variety exceed a certain limit, now thought to be from 50 to 60, it is likely to exhibit many bursters and to show many of the abnormal variations common to the double flower.

NATURE OF DOUBLING IN THE CARNATION FLOWER

A study of the literature upon this point at once reveals the fact that the *Dianthus* in general, and the carnation in particular, is subject to practically all of the morphological modifications found in the floral parts of a flower. On this subject Bateson¹ has made the following statement: "In carnation, where the doubling is of the ordinary kind, due to petalody combined with the subdivision of parts, there is some reason for suspecting doubleness to be a dominant." Some very unusual cases of variation in the carnation flower are cited by Masters.² Two of the most interesting of these are here given. Under adventitious buds he mentions an instance in which the stamens were completely suppressed, their places being usurped by flower-bearing branches.³ In discussing proliferation of the inflorescence he cites an instance in which the calyx of a proliferous pink was prolonged and produced from its side a successive series of sepals as in what is called the "wheat ear carnation."⁴

¹Bateson, W. "Mendel's Principles of Heredity," p. 200, (1909).

²Masters, M. T. "Vegetable Teratology," (1869).

³Loc. cit., pp. 145-146.

⁴Loc. cit., pp. 129, 372.

Phyllody of the ovules of the carnation was noted by Berkeley.¹ Of this phenomena he says, "Amongst a number of the ordinary nearly colorless ovules six or seven much larger green bodies appeared, each surmounted by a white subulate process. On further examination these were found to be almost cartilaginous with a strong suture on the outer side and a very faint one behind, being evidently abortive ovaries terminated by a stigma longer than themselves. After some search another was found in which the placenta was divided into three distinct parts, two of them connected with the stigma by the usual cord and bearing normal ovules, the other having three more or less perfectly formed ovaries, the upper and lower of which alone were furnished with a stigma, though all bore towards their base imperfect ovules, etc."

The writer has been able to observe practically all of the variations occurring outside of the ovary, except that of the "wheat ear" phenomena. Homeosis, or the assumption of one part by another as in petalody of the stamens as a whole and the anther in particular, is of quite common occurrence. Homeotic variation is not often noted in the sepals; only one such case thus far has come to the writer's attention. In this instance the upper portion of a sepal was converted into a petal. Meristic variation or the repetition of parts; multiplication by division or fission of the petals and stamens; and proliferation of the petals, are also common occurrences.

¹Berkeley, J. M. Gard. Chron., p. 612, (1850).

SUMMARY

The data herein presented, taken in connection with that published by Norton and cited in the text, seems to justify the following conclusions:

1. That the commercial carnation as grown by florists is a heterozygote or unfixed hybrid of a cross between the single and double carnation:

2. That the single is recessive to the double:

3. That singles x singles produce only singles:

4. That commercials x singles give practically an equal number of each:

5. That commercials x commercials give very nearly the expected ratio of singles:

6. That commercial and double together closely approximate the required ratio:

7. That the progeny of single x double, of which there were 1,004, were all of the commercial type except four which were single, the presence of which may possibly be ascribed to error in technique:

8. That crosses between single and double carnations were more prolific than were the other crosses, a fact of importance in carnation breeding:

9. That the "bursting" commonly occurring in leading varieties may be largely due to the formation of adventitious buds in the flower, rather than to inherent weakness of the calyx or to unfavorable temperatures shortly before the flowers open. The cause, whatever it may be, occurs at a much earlier stage in the development of the flower:

10. That carnation doubling is due to a variety of morphological modifications of the floral organs.

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UNIV. OF MICHIGAN,

17 1912
UNIVERSITY OF VERMONT

AND STATE AGRICULTURAL COLLEGE

VERMONT AGRICULTURAL
EXPERIMENT STATION

BURLINGTON, VT.

BULLETIN No. 164

MARCH, 1912

Commercial Feeding Stuffs

Commercial Feeds

- I. SUMMARY—Page 75.
- II. RESULTS OF INSPECTION—Pages 76-100.
- III. DISCUSSION OF THE RESULTS OF INSPECTION—Pages 101-121.
- IV. CONDIMENTAL FEEDS—Pages 122-133.

NOTE.—No. 163, on the "Mendelian Inheritance in the Carnation," a technical bulletin, will not be distributed to the general lists. It will be sent without charge on application.

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1912.

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☞ Address all communications not to individual officers but to the Experiment Station, Burlington, Vt.

Director's and State Forester's offices, chemical, horticultural and dairy laboratories are in Morrill Hall at the head of Main street; botanical and bacteriological laboratories are at Williams Science Hall, University Place; veterinary laboratories at 499 Main Street.

Experiment farm and buildings are on the Williston road, adjoining the University grounds on the east.

*In cooperation with Bu. An. Ind., U. S. Dept. Agr.

**BULLETIN 164: COMMERCIAL FEEDING STUFFS
CONDIMENTAL FEEDS**

By J. L. HILLS, C. H. JONES, P. A. BENEDICT and W. B. DERBY

I. SUMMARY

Some 400 samples of feeding stuffs were drawn in late November and early December, 1911, from dealers' stocks. Analyses were made of most of the goods in full for the first time in the history of the inspection in this state. Protein guaranties as a whole were well kept; fat guaranties fairly well maintained; fiber guaranties often were but ill kept. Two cottonseed meals ran too high in fiber (too many hulls); three cottonseed feed meals (so-called but misnamed) were up to guaranty, but are characterized as uneconomical purchases; one proprietary feed was shy in protein. As a whole the outcome was very satisfactory, but there seems need of more attention on the part of some manufacturers to the maintenance of their fiber guaranties.

Condimental stock and poultry foods are reported on at considerable length on the last ten pages of the bulletin. Their nature, the claims made for them, the economy of purchase, etc., are reviewed.

The chemical analyses of the various feeding stuffs and condimental feeds appear on pages 78-100, 124-125; and statements concerning the several goods are to be found on pages 101-120, 126-131.

II. RESULTS OF INSPECTION

The sampling agents of the Station visited fifty towns and villages in Vermont in late November and early December, 1911, and drew 404 samples from dealers' stocks, representing 276 brands of goods which either are subject to, or are exempt from, the necessity of guaranty. All of these samples were examined chemically for protein. Both guaranteed and unguaranteed goods were analyzed: the former to determine so far as might be their purity, as well as the maintenance of the standards fixed by the manufacturers; the latter to determine, if possible, whether as a matter of fact the goods were pure and not subject to guaranty.

For the first time since 1899, when the inspection law took effect, complete analyses have been made. At no time in the past twelve years has it been possible to make more than the determinations of moisture, protein, and fat, and, during the past ten years, with an annual appropriation of only five hundred dollars, it has been possible to make simply the bare bones of an inspection, and to determine the protein contents only. This is a different procedure than that which is carried out by other feeding stuffs inspections throughout the country, all of which receive larger sums for the enforcement of the law than are appropriated in Vermont. The unfavorable results attained at times elsewhere seemed to indicate that it might be worth while, at least occasionally, to attempt to do thorough work in Vermont; to raise the pertinent question whether, because of the necessarily inadequate inspectional work done here, it might not be true that some manufacturers and shippers were using Vermont as an outlet for inferior materials. The present time seemed auspicious for the determination of this matter, in view of the fact that there had accumulated in the state treasury quite a large proportion of the appropriation. The inspections of the last year or two had been conducted with a view of making savings even from the small annual appropriation, in order to determine whether this hypothesis had any basis in fact. The re-

sults attained in the present inspection, as will be pointed out later, indicate that in certain cases there was some reason for the suspicion that the ingredients which the Vermont law requires to be guaranteed, but which under the circumstances it has been impracticable for the Station to determine by analysis, were not being looked after as carefully by the manufacturers as is the protein content of their goods. So far as the protein is concerned, the results of the present inspection are extremely satisfactory, but few shortages occurring, and these not serious ones.

The reader who may be interested in the economics of feed purchase is referred to matter on pages 34 to 44 of bulletin 144, as well as to that on pages 582 to 590 of bulletin 152. Full descriptions of the nature and manufacture of the sundry goods offered on Vermont market will be found on pages 22 to 34 of bulletin 144, together with a discussion of the advisability or inadvisability of their purchase, as the matter appealed to the writer at the time that bulletin was written (1909).

NAME AND ADDRESS
OF
MANUFACTURER OR JOBBER

SAMPLED AT

COTTONSEED MEAL

See statements concerning analyses and values,
pages 101-102, 116-120.

Humphreys, Godwin & Co., Memphis, Tenn. Burlington, Rutland, St. Alb's

Humphreys, Godwin & Co., Memphis, Tenn. Waterbury

F. W. Brod  Co., Memphis, Tenn. Pittsford, Winooski, Wood-
stock, Swanton

Buckeye Cotton Oil Co., Cincinnati, O. . . Montpelier, Manchester, Rut-
land, Brattleboro

Buckeye Cotton Oil Co., Cincinnati, O. . . Putney

S. P. Davis, Little Rock, Ark. Fair Haven, Barton

S. P. Davis, Little Rock, Ark. Bethel

American Cotton Oil Co., Memphis, Tenn. Brattleboro, Burlington

J. E. Soper, Boston, Mass. Proctorsville

J. E. Soper, Boston, Mass. Barre

J. Lindsey Wells, Memphis, Tenn. Randolph

Memphis Cottonseed Products Co., Mem-
phis, Tenn. Wallingford

COTTONSEED FEED MEAL

See statements concerning analyses and values,
pages 102-103, 116-120.

Humphreys, Godwin & Co., Memphis, Tenn. Montpelier, Essex Junction,
St. Albans

Tennessee Fiber Co., Memphis, Tenn. . . . St. Albans

Humphreys, Godwin & Co., Memphis, Tenn. Woodstock

BRAND NAME	ANALYSES							GUARANTIES		
	Moisture	Crude ash	Crude protein	Crude fiber	Nitrogen-free extract matter	Ether extract	Selling prices	Crude protein	Crude fiber	Ether extract

COTTONSEED MEAL

Cottonseed meal is the ground residue obtained in the extraction of oil from the cottonseed kernel after the removal of the hulls.

Dixie,	7.90	6.86	40.31	8.63	27.62	8.68	\$31.25	38.62	8.	6.
							-35			
Dixie,	8.10	5.85	39.44	10.64	28.73	7.24	33.	38.	8.	6.
Owl,	7.85	7.56	41.63	6.84	27.67	8.45	32-34	41.	10.	6.
Buckeye,	7.88	6.60	39.91	8.98	28.55	8.08	32-35	38.5	8.	6.5
Buckeye,	7.53	5.84	38.47	11.14	28.40	8.62	34	39.	8.	6.
Goodluck,	7.49	6.90	44.85	6.57	25.35	8.84	32-33	41.	10.5	7.
	8.09	6.01	41.19	10.72	27.01	6.98	30	41.	10.5	7.
Choice,	8.65	6.32	41.88	9.30	25.86	7.99	33-35	41.	10.5	9.
Soper's,	8.39	6.74	42.32	6.54	27.46	8.55	33	41.	—	8.
Pioneer,	7.70	7.70	42.32	6.95	25.98	9.35	33	41.	10.	8.
Sun,	8.01	6.07	40.10	8.07	26.77	10.98	33	41.	7.	9.
Selden's,	7.98	7.47	41.53	8.58	26.13	8.31	—	41.	10.	6.

COTTONSEED FEED MEAL

Cottonseed feed meal is a misnomer. The proper name is cottonseed feed. This is a mixture of cottonseed meal and cottonseed hulls, containing less than 36 percent protein. The hulls are the outer portion of the cottonseed, high in crude fiber and of relatively little feeding value. They are a roughage and not a concentrate.

							\$28-			
Cremo,	8.36	5.10	24.31	19.99	35.57	6.67	31.50	22.	22.	5.
	9.30	5.03	23.25	20.84	36.65	4.93	—	22.	25.	4.5
Cremo,	7.92	5.21	24.43	20.35	36.49	5.60	31	22.	22.	5.

NAME AND ADDRESS
OF
MANUFACTURER OR JOBBER

SAMPLED AT

LINSEED MEAL

See statements concerning analyses and values,
pages 103-104, 116-120.

American Linseed Co., Chicago, Ill.....Newport
American Linseed Co., New York, N. Y...Proctorsville, Waterbury
Guy G. Major Co., Toledo, O.Barton, Burlington, Winooski
Red Wing Linseed Co., Red Wing, Minn..Proctorsville, Fair Haven
Midland Linseed Co., Minneapolis, Minn..Putney

"LINOMEAL"

A. A. Beltz, Minneapolis, Minn.Brattleboro

GLUTEN FEEDS

See statements concerning analyses and values,
pages 104, 116-120.

Corn Products Refining Co., New York...Proctorsville, Bennington,
Waterbury
Corn Products Refining Co., New York...St. Albans
Clinton Sugar Refining Co., Clinton, Ia..Montpelier, Burlington, Swan.
Corn Products Refining Co., New York..Putney, Randolph
Corn Products Refining Co., New York..Poultney
Douglas & Co., Cedar Rapids, Ia.....Manchester
Douglas & Co., Cedar Rapids, Ia.....Rutland
American Maize Products Co., New York..St. Johnsbury

CORN OIL MEAL

See statements concerning analyses and values,
pages 104-105, 116-120.

Corn Products Refining Co., New York..St. Albans

BRAND NAME	ANALYSES						GUARANTIES		
	Moisture	Crude ash	Crude protein	Crude fiber	Nitrogen-free extract matter	Ether extract	Selling prices	Crude protein	Crude fiber	Ether extract

LINSEED MEAL

Linseed meal is the ground residue obtained in the extraction of a part of the oil from flaxseed. The "old process" meal is made from crushed flaxseed which has been heated and subjected to hydraulic pressure; the "new process" meal is made from crushed flaxseed which has been extracted after heating by repeated leachings with light naphtha, all traces of which are removed by steam treatment. The latter goods carry but half the fat content of the former and usually from one to two percent more protein.

	8.38	8.11	37.25	7.40	35.27	3.59	\$42	36.	6.	1.
Old Process,	7.90	6.40	38.13	7.12	33.33	7.12	40-42	32.	7.	5.
Old Process,	7.64	7.27	33.75	8.49	35.99	6.86	34-42	30.	10.	5.
Gr. Oil Cake,	6.62	6.84	37.82	6.69	33.90	8.13	44-45	30.	9.	6.
Old Process,	8.15	6.29	37.38	7.72	32.93	7.53	44.50	32.	8.5	6.

"LINOMEAL"

Linomeal,	7.78	8.37	17.88	9.44	47.38	9.15	\$22	16.	12.	8.
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GLUTEN FEEDS

Gluten feed is a product obtained in the manufacture of starch and glucose from corn and is a mixture of gluten meal, corn bran, germ residues, and, permissibly, "steep water" residues. It consists largely of the flinty portion of the outer coatings of kernel, being essentially the corn grain with its starchy portion largely removed.

Buffalo,	7.73	4.95	27.16	5.91	50.99	3.26	\$30-35	24.	8.5	2.5
Buffalo,	7.11	4.48	28.40	6.26	50.45	3.30	32.50	23.	8.5	2.5
Clinton,	8.03	1.68	25.54	6.83	54.19	3.73	31.50	20.	7.5	3.
							-34			
Crescent,	7.28	5.93	28.06	6.44	49.50	2.79	33	23.	8.5	2.5
Globe,	8.00	4.55	28.40	6.17	49.83	3.05	—	23.	8.5	2.5
Cedar Rapids,	7.64	1.16	24.13	6.66	57.38	3.03	33	20.	8.	3.
Cedar Rapids,	6.15	1.16	22.69	7.84	58.95	3.21	33	20.	8.	3.
Cr. of Corn,	6.76	4.33	26.27	6.26	54.15	2.23	31.50	23.	8.5	2.5

CORN OIL MEAL

Corn oil meal (corn germ meal) is a product of the manufacture of starch, glucose, and other corn products and is the germ layer from which a part of the corn oil has been extracted by hydraulic pressure.

Argo

corn oil meal,	7.03	2.31	21.15	8.68	52.47	8.36	29.50	19.	15.	7.5
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NAME AND ADDRESS OF MANUFACTURER OR JOBBER	SAMPLED AT
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DISTILLERS' DRIED GRAINS

See statements concerning analyses and values,
pages 105, 116-120.

Ajax Mill & Feed Co., Buffalo, N. Y.....	Pittsford
J. W. Biles Co., Cincinnati, O.....	Brattleboro, Burlington
Deutsch & Sickert Co., Milwaukee, Wis..	Rutland
Griswold & MacKinnon, St. Johnsbury, Vt..	Barton, Windsor, Montpelier
Hottelet Co., Milwaukee, Wis.....	St. Albans, Brattleboro, Mont.
J. D. Page & Co., Syracuse, N. Y.....	Enosburg Falls, Bellows Falls, Randolph
Clifton Springs Distillers Co., Cincinnati.	Wallingford
Husted Milling Co., Buffalo, N. Y.....	Orleans

BREWERS' DRIED GRAINS

See statements concerning analyses and values,
pages 105-106, 116-120.

Schlitz Brewing Co., Milwaukee, Wis....	Swanton
Hottelet Co., Milwaukee, Wis.....	Vergennes
Anheuser Busch Brewing Co., St. Louis.	Montpelier
Francis Duhue, Jr., Milwaukee, Wis.....	Winooski
Francis Duhue, Jr., Milwaukee, Wis.....	St. Albans

PROPRIETARY FEEDS

See statements concerning analyses and values,
pages 106-107, 116-120.

J. W. Biles Co., Cincinnati, O.....	Swanton, Rutland, Middle- bury, Waterbury
Chapin & Co., Milwaukee, Wis.....	Barton, Rutland, Middlebury
Quaker Oats Co., Chicago, Ill.....	Randolph
C. M. Cox Co., Boston, Mass.....	St. Albans
C. M. Cox Co., Boston, Mass.....	Randolph
Burlington Flouring Co., Burlington, Vt.	Burlington
St. Albans Grain Co., St. Albans, Vt....	St. Albans
J. W. Biles Co., Cincinnati, O.....	_____

BRAND NAME	ANALYSES							GUARANTIES		
	Moisture	Crude ash	Crude protein	Crude fiber	Nitrogen-free extract matter	Ether extract	Selling prices	Crude protein	Crude fiber	Ether extract

DISTILLERS' DRIED GRAINS

Distillers' dried grains are the dried residues obtained from cereals in the manufacture of alcohol and distilled liquors. (The following samples are derived largely, if not entirely, from corn):

Ajax Flakes,	5.21	3.17	30.38	10.75	39.44	11.05	—	31.33	12.18	12.
XXXX Gr'ns,	5.09	2.39	30.06	11.53	39.53	11.40	\$33-34	31.	13.	12.
Chimax Gr'ns,	5.15	2.19	31.25	11.73	37.39	12.29	34	30.	—	10.
Extra Good,	5.43	2.09	31.58	10.34	35.90	14.66	28-33	30.	—	10.
Hector,	5.25	1.95	29.50	10.67	40.07	12.56	31.50	30.	14.	10.
							-33			
Empire State,	5.06	2.27	30.82	10.69	40.34	10.82	32.34	29.	12.50	12.
Imperial Corn,	4.48	2.73	30.27	11.66	37.98	12.88	29	28.	—	8.
Husted	5.50	1.92	29.60	10.27	40.65	12.06	32	30.	9.	8.

BREWERS' DRIED GRAINS

Brewers' dried grains are the dried residues obtained from cereals in the manufacture of malted liquors.

Malt sprouts are the dried sprouts of the barley grain removed after the process of malting has taken place.

Schlitz Purity,	5.84	3.62	27.19	15.29	44.35	3.71	—	26.	14.	6.
Holstein,	6.23	3.47	26.94	14.06	45.11	4.19	\$31	25.	14.	5.07
	5.77	4.21	23.69	15.77	45.76	4.80	29.50	24.	12.	7.5
Tomahawk,	5.18	3.51	28.97	13.40	43.78	5.16	28	26.	14.	6.
Malt Sprouts,	8.28	5.91	25.88	12.73	45.64	1.56	—	25.	11.	2.

PROPRIETARY FEEDS

Proprietary feeds are admixtures of several feeding stuffs.

Union Grains,	5.90	5.13	25.66	9.21	46.22	7.88	\$34	24.	9.	7.
Unicorn D'ry,	5.91	4.47	26.31	9.68	46.99	6.64	26-34	26.	10.	5.5
Blue Rib. D'y,	6.00	7.04	20.94	11.76	51.11	3.15	32	25.	—	—
Wirthmore,	6.72	5.11	27.38	9.57	46.63	4.59	32	25.5	9.	5.2
Wirthmore,	6.53	5.93	26.40	9.13	47.30	4.71	34	26.	—	5.7
Perf'n Dairy,	6.24	5.19	24.35	10.40	47.69	6.13	31	22.	—	5.
Paragon D'y,	8.12	5.93	27.29	8.10	44.73	5.83	—	28.	—	5.
Ubiko Horse,	6.55	3.98	18.19	8.96	55.23	7.09	—	16.	9.	6.

NAME AND ADDRESS OF MANUFACTURER OR JOBBER	SAMPLED AT
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CORN AND OAT FEEDS

See statements concerning analyses and values,
pages 107-108, 116-120.

Quaker Oats Co., Chicago, Ill.....	Pittsford
Quaker Oats Co., Chicago, Ill.....	Rutland, Montpelier
American Cereal Co., Chicago, Ill.....	Poultney
A. H. McLeod Milling Co., St. Johnsbury	St. Johnsbury
C. M. Cox Co., Boston, Mass.....	Windsor, Enosburg Falls
Griswold & MacKinnon, St. Johnsbury, Vt.	Newbury
H. O. Co., Buffalo, N. Y.....	Bellows Falls
J. H. Hewitt, South Royalton, Vt.....	So. Royalton
Commercial Milling Co., Detroit, Mich...	Proctorsville
Ferguson & Bedall, Boston, Mass.....	Brattleboro
W. H. Haskell & Co., Toledo, O.....	Barre
C. M. Cox Co., Boston, Mass.....	St. Albans
Commercial Milling Co., Detroit, Mich...	Winooski
Buffalo Cereal Co., Buffalo, N. Y.....	Poultney
Ogdensburg Roller Mills Co., Ogd'sb'g, N. Y.	Charlotte

MOLASSES FEEDS

See statements concerning analyses and values,
pages 108-113, 116-120.

Quaker Oats Co., Chicago, Ill.....	Rutland, Orleans, Randolph
American Milling Co., Chicago, Ill.....	B. Falls, Newport, Randolph
Husted Milling Co., Buffalo, N. Y.....	Rutland, Middlebury, Randolph
Husted Milling Co., Buffalo, N. Y.....	Orleans
Northwest Mills Co., Winona, Minn....	Rutland, Brandon
Northwest Mills Co., Winona, Minn....	Enosburg Falls
Northwest Mills Co., Winona, Minn....	Chester, Middlebury
Northwest Mills Co., Winona, Minn....	Burlington
Northwest Mills Co., Winona, Minn....	Montpelier
Sugarine Co., Chicago, Ill.....	Barton

BRAND NAME	ANALYSES							GUARANTIES		
	Moisture	Crude ash	Crude protein	Crude fiber	Nitrogen-free extract matter	Ether extract	Selling prices	Crude protein	Crude fiber	Ether extract

CORN AND OAT FEEDS

Corn and oat feeds are proprietary mixtures into the compounding of which considerable quantities of oat by-products as well as corn enter. They usually carry less than 12 percent protein and from 8 percent upwards of crude fiber. "Chop" is a ground or chop feed composed of one or more different cereals or the by-products therefrom.

Schumaker's										
Stock,	7.51	4.02	10.50	8.00	66.13	3.84	—	10.	10.	3.25
Schumaker's										
Stock,	7.04	3.86	11.38	9.34	64.54	3.84	\$31.50	10.	10.	3.25
							-34			
Victor,	7.20	3.64	9.88	8.23	67.23	3.72	30	7.5	12.	3.
Brooks' Fancy										
C. & O.,	8.43	3.51	10.50	9.32	65.10	3.14	34	7.63	—	2.97
Wirthmore										
Stock,	9.13	2.93	10.06	6.99	65.54	5.35	32-33	9.	—	4.
Just as Good,	7.78	3.99	10.31	7.92	64.35	5.65	33	7.5	12.	3.
Peerless St'k,	7.16	4.50	9.88	11.00	63.30	4.16	30	8.5	11.5	3.25
Stock,	7.36	3.29	9.88	8.83	66.11	4.53	—	—	—	—
Henkel's Chop,	8.26	2.72	10.06	5.67	67.61	5.68	33	8.	7.	5.
Honor Bright										
Chop,	8.39	2.97	10.50	6.52	66.48	5.14	30	8.	—	3.
Haskell's Stk.,	7.42	3.38	10.75	5.96	65.99	6.50	32	8	6.	4.
Charlestock,	7.59	3.50	9.00	9.28	65.79	4.84	28.50	6.	—	3.
Waumbeck										
Stable,	8.66	2.74	9.44	6.00	68.22	4.94	32	9.7	8.75	5.35
Buffalo C. E.										
Co. Stock,	6.54	3.42	9.63	8.70	66.15	5.56	33	8.	9.	4.
	8.35	2.38	8.31	9.01	69.21	2.74	36	—	—	—

MOLASSES FEEDS

Molasses feeds are proprietary feeds, admixtures of several feeding stuffs, usually both of low and of high grade, together with molasses.

Quaker Dairy										
Molasses,	5.75	8.86	15.78	15.94	49.25	4.42	\$26-30	16.	12.	3.5
Sucrene Dairy,	6.96	9.47	18.63	10.87	49.40	4.67	27-28	16.5	12.	3.5
Husted,	8.40	7.88	23.03	8.05	47.83	4.81	30-32	18.	8.	4.
Husted,	7.89	7.76	24.00	8.45	47.09	4.81	30	16.	8.	4.
Sugarota D'y,	7.25	8.44	16.44	15.65	47.49	4.73	26	16.	12.	3.
" D'y,	7.30	8.21	17.00	13.09	49.84	4.56	24	16.5	14.	3.5
" Mills,	6.62	7.29	24.88	11.90	45.17	4.14	34	25.	9.	6.
" Swine,	7.49	6.32	17.78	9.58	55.54	3.29	30	18.	—	4.5
" Horse,	6.38	7.41	13.81	14.29	52.77	5.34	27	12.	—	3.5
Sugarine D'y,	7.45	8.40	17.88	12.47	49.50	4.30	27	16.5	12.	3.5

NAME AND ADDRESS
OF
MANUFACTURER OR JOBBER

SAMPLED AT

MISCELLANY

See statements concerning analyses and values,
pages 113-114, 116-120.

Quaker Oats Co., Chicago, Ill.....Fair Haven, Bellows Falls,
Enosburg Falls, Barre

Northwest Mills Co., Winona, Minn.....Brandon

Blatchford's Calf Meal Co., Waukegan, Ill.Middlebury

Michigan Sugar Co., Alma, Mich.....St. Albans

Buffalo Cereal Co., Buffalo, N. Y.....Bellows Falls

.....Brandon

German-Amer. Sugar Co., Bay City, Mich.Brandon

West Bay City Sugar Co., Bay City, Mich.St. Albans, Montpelier

Owasso Sugar Co., Owasso, Mich.....Rutland, Middlebury

Boutwell Milling & Grain Co., Troy, N. Y.Brandon, Rutland

Washburn-Crosby Milling Co., Minneapo-

lis, Minn.Brattleboro

H. W. Putnam, Bennington, Vt.....Bennington

PROVENDERS (*local grindings*)

Provender is a straight mixture of corn and oats ground together
without extraneous material.

Mrs. E. H. Atherton, Cavendish, Vt.....Cavendish

A. H. McLeod Milling Co., St. Johnsbury.St. Johnsbury

C. C. Colvin, Manchester, Vt.....Manchester

Davis Feed Co., Rutland, Vt.....Rutland

Davis Feed Co., Rutland, Vt.....Rutland

BRAND NAME	ANALYSES							GUARANTIES		
	Moisture	Crude ash	Crude protein	Crude fiber	Nitrogen-free extract matter	Ether extract	Selling prices	Crude protein	Crude fiber	Ether extract

MISCELLANY

Calf meals are proprietary feeds intended as whole or partial substitutes for milk in the feeding of young calves.

Hominy meal, feed or chop is a by-product of the manufacture of hominy grits from corn, and consists of the bran coating or hull and corn germ, together with a considerable portion of the cornstarch.

Alfalfa meal is the entire alfalfa hay ground without admixture of ground alfalfa straw or other foreign materials.

Dried beet pulp is the dried sugar beet residue obtained in the manufacture of beet sugar, with or without an admixture of beet molasses.

Rye feeds are by-products obtained in the manufacture of rye flour.

Schumaker's										
Calf Meal,	7.13	4.08	19.50	1.35	61.68	6.26	\$60	19.	3.	8.
Sugarota										
Calf Meal,	8.22	4.60	25.63	4.95	51.43	5.17	70	25.	—	6.
Blatchford's										
Calf Meal,	6.73	5.95	25.44	6.45	49.85	5.58	60-65	25.	5.	5.
Dr. Beet Pulp										
& Molasses,	5.80	4.06	9.19	18.43	62.06	0.46	25.75	9.	18.	0.5
Hominy,	7.82	2.77	9.50	3.58	69.13	7.20	—	—	—	—
Alfalfa,	6.62	9.11	14.69	31.65	36.64	1.29	32	—	—	—
Dr. Beet Pulp,	7.43	4.15	9.19	18.54	59.96	0.73	30	8.	20.	0.5
Dr. Beet Pulp,	7.68	2.90	9.19	18.29	61.24	0.70	25.75	8.	20.	0.5
							26.50			
Dr. Beet Pulp,	7.65	2.74	8.13	19.40	61.39	0.69	26-30	8.	20.	0.5
Rye feed,	8.38	4.25	16.78	4.23	63.16	3.20	32	13.5	—	3.
Rye Middl'gs,	8.41	3.96	18.00	4.97	61.06	3.60	29.50	14.	8.	3.
Buckw't Bran,	7.29	3.09	15.81	4.99	64.97	3.85	—	—	—	—

PROVENDERS (*local grindings*)

See statements concerning analyses and values,
pages 114, 116-120.

—	8.64	2.05	11.19	3.17	70.54	4.41	\$35	—	—	—
—	9.40	2.19	11.19	4.21	68.91	4.10	36	—	—	—
—	9.13	1.96	10.50	3.31	71.00	4.10	38	—	—	—
—	9.18	2.28	10.75	4.58	69.73	3.48	—	—	—	—
—	8.98	2.60	11.19	5.15	68.38	3.70	—	—	—	—

Five other samples drawn elsewhere carried from 10.50-12.06 percent crude protein.

NAME AND ADDRESS OF MANUFACTURER OR JOBBER	SAMPLED AT
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CORN MEAL

See statements concerning analyses and values,
pages 114, 116-120.

Mrs. E. H. Atherton, Cavendish, Vt.....Cavendish
 Burlington Flouring Co., Winooski, Vt..Winooski
 C. C. Colvin, Manchester, Vt.....Manchester
 H. B. Townshend, Wallingford, Vt.....Wallingford
 H. W. Myers, Bennington, Vt.....Bennington

POULTRY FEEDS

Animal meals, meat scraps, etc.

See statements concerning analyses and values,
pages 114-115, 116-120.

Bowker Fertilizer Co., Boston, Mass....Brattleboro, Waterbury

Burlington Rendering Co., Burlington, Vt.Bristol
 Burlington Rendering Co., Burlington, Vt.St. Johnsbury, Fair Haven
 Burlington Rendering Co., Burlington, Vt.St. Albans, Bellows Falls, No.
 Bennington

C. S. Page, Hyde Park, Vt.....Manchester

Swift's Lowell Fertilizer Co., Boston....Rutland

Van Iderstine Co., Long Island City, N. Y.St. Albans
 Van Iderstine Co., Long Island City, N. Y.Norwich

Van Iderstine Co., Long Island City, N. Y.Norwich

SCRATCH FEEDS

E. Crosby & Co., Brattleboro, Vt.....Brattleboro
 C. M. Cox Co., Boston, Mass.....White River Junction
 A. Dickinson Co., Chicago, Ill.....Bennington
 H. O. Co., Buffalo, N. Y.....Bellows Falls
 E. T. & H. K. Ide, St. Johnsbury, Vt....Bradford

Park & Pollard Co., Boston, Mass.....No. Bennington, Northfield
 Quaker Oats Co., Chicago, Ill.....Randolph

CHICK FEEDS: GROWING FEEDS

C. M. Cox Co., Boston, Mass.....St. Albans

C. M. Cox Co., Boston, Mass.....Waterbury

BRAND NAME	ANALYSES							GUARANTIES		
	Moisture	Crude ash	Crude protein	Crude fiber	Nitrogen-free extract matter	Ether extract	Selling prices	Crude protein	Crude fiber	Ether extract

CORN MEAL

_____	9.75	1.60	9.88	1.98	72.65	4.14	\$33	—	—	—
_____	9.88	1.52	9.88	1.85	72.98	3.89	33	—	—	—
_____	9.77	1.60	9.88	1.95	72.48	4.32	36	—	—	—
_____	9.85	1.53	9.63	2.26	72.79	3.94	—	—	—	—
_____	10.19	1.76	9.88	1.75	72.13	4.29	34	—	—	—

POULTRY FEEDS

Animal meals, meat scraps, etc.

Animal meat, meat scraps, or meat meal is finely ground beef scraps, including more or less bone as well as meat.

Bowker's,	4.82	33.85	44.32	1.37	6.07	9.57	\$45-50	40.	1.5	5.
B. R. Co.'s										
Bone & Meat,	3.86	—	34.98	—	—	—	—	40.	—	8.
Bone & Meat,	5.13	34.90	42.94	1.53	3.02	12.48	50-70	35.	—	8.
Cooked Scrap,	5.13	36.84	43.88	0.79	2.27	11.09	55	40.	—	8.
Page's										
Gr'd Scrap,	6.51	18.83	56.38	1.13	0.40	16.75	70	55.	—	10.
Swift's Low-										
ell Cooked,	4.75	37.88	42.75	0.56	3.78	10.28	65	40.	—	8.
Darling's										
Beef Scrap,	5.16	23.55	58.75	2.11	—	12.20	—	55.	3.	10.
Darling's,	5.63	21.28	60.75	—	0.76	11.58	60	55.	3.	5.
Darling's										
Beef Meal,	5.66	24.54	50.63	3.84	5.76	9.57	46	45.	3.	10.

SCRATCH FEEDS

Fancy,	9.88	8.63	11.19	2.22	65.80	2.28	38	10.	5.	2.5
Wirthmore,	10.60	1.65	11.19	2.95	70.41	3.20	—	10.	—	3.
Globe,	9.43	2.26	11.63	2.04	71.95	2.69	42	10.	5.	2.5
All Grain,	9.64	1.74	11.19	2.38	71.55	3.50	40	11.	9.	3.5
Ideal,	10.25	2.03	11.38	4.04	67.77	4.53	40	14.	(with fat)	
Park &										
Pollard,	10.28	2.24	12.06	3.67	68.34	3.41	42	10.	—	3.
Schumaker,	9.71	1.88	11.81	2.24	70.94	3.42	40	10.	5.	2.5

CHICK FEEDS: GROWING FEEDS

Wirthmore										
Growing,	9.43	2.32	11.81	3.21	70.08	3.15	\$39	13.	—	4.
Wirthmore										
Chick,	5.66	1.76	12.50	1.35	73.79	4.94	40	11.	—	3.

NAME AND ADDRESS
OF
MANUFACTURER OR JOBBER

SAMPLED AT

CHICK FEEDS: GROWING FEEDS—*Continued*

W. S. Hills Co., Boston, Mass.....Bellows Falls

Husted Milling Co., Buffalo, N. Y.....Charlotte

Park & Pollard Co., Boston, Mass.....Brattleboro

Park & Pollard Co., Boston, Mass.....Swanton

Park & Pollard Co., Boston, Mass.....Brattleboro

Van Iderstine Co., Long Island City, N. Y.Norwich

MASHES

C. M. Cox Co., Boston, Mass.....Waterbury White River Jct.

C. M. Cox Co., Boston, Mass.....St. Albans

Albert Dickinson Co., Chicago, Ill.....Brattleboro

W. S. Hills Co., Boston, Mass.....Bellows Falls

Model Milling Co., Buffalo, N. Y.....Bennington

Park & Pollard Co., Boston, Mass.....Montpelier, Swanton, No. Ben.

W. R. White, No. Bennington, Vt.....No. Bennington

MISCELLANY

American Milling Co., Chicago, Ill. Bradford

Federal Food Co., Mifflinsburg, Pa.....Woodstock

C. S. Page, Hyde Park.....Bennington

C. S. Page, Hyde Park.....Barre, St. Johnsb'y, Manch'r

Park & Pollard Co., Boston, Mass.....Montpelier, Swanton, Brat.

Quaker Oats Co., Chicago, Ill.....Rutland

BRAND NAME	ANALYSES							GUARANTIES		
	Moisture	Crude ash	Crude protein	Crude fiber	Nitrogen-free extract matter	Ether extract	Selling prices	Crude protein	Crude fiber	Ether extract

CHICK FEEDS: GROWING FEEDS—*Continued*

Purity Growing,	7.70	10.25	13.70	3.66	60.86	3.83	40	17.5	8.25	4.9
Husted Chick,	10.13	2.38	12.06	2.05	70.68	2.70	45	—	—	—
Park & Pollard Chick,	10.52	2.97	11.81	1.65	70.83	2.22	44	10	—	2.77
Park & Pollard Growing,	9.51	7.84	16.00	2.67	60.64	3.34	47	15.	—	4.
Intermed.Ch.,	9.44	1.90	12.69	1.65	71.26	3.06	41.50	10.	—	3.
Darling Ch.,	10.01	2.26	11.38	2.43	71.02	2.90	43	8.	10.	1.

MASHES

Wirthmore Complete Ration,	8.79	9.31	20.38	5.19	52.56	3.77	\$42	17.	—	4.
Wirthmore Complete Ration,	9.55	3.73	14.00	6.74	62.39	3.59	35.50	12.	—	3.
Queen,	8.41	3.41	11.81	6.09	66.80	3.48	—	11.	10.	2.5
Purity,	6.48	20.40	13.38	4.38	51.76	3.60	40	16.1	16.7	4.9
Egg,	7.40	6.70	18.63	11.84	52.46	2.97	40	—	—	—
Dry,	8.24	12.03	20.19	7.87	47.58	4.09	44-48	20.	—	3.
Flynn's,	7.57	10.30	21.50	8.66	46.19	5.78	40	—	—	—

MISCELLANY

Am. Co. Hen,	8.84	2.27	12.06	3.03	70.77	3.03	\$40	10.	5.	3.
Federal Food,	4.12	32.14	18.19	9.70	22.89	12.96	—	17.	8.22	12.
Page's,	6.41	60.36	22.13	1.29	3.25	6.56	—	—	—	—
Page's Perfd,	7.17	46.85	26.94	3.49	9.99	5.56	70-72	24.	—	8.
Fattening,	9.70	3.07	11.38	3.90	69.69	2.26	37.50	10.	—	3.
							43.50			
American,	8.91	3.16	14.69	4.45	63.75	5.04	40	12.	—	3.5

NAME AND ADDRESS
OF
MANUFACTURER OR JOBBER

SAMPLED AT

WHEAT OFFALS

Brans

See statements concerning analyses and values,
pages 115-116, 116-120.

Northwestern Consolidated Milling Co.,
Minneapolis, Minn. Rutland
Russell Milling Co., Albany, N. Y. Charlotte
Amendt Milling Co., Detroit, Mich. Bradford
Barber Milling Co., Minneapolis, Minn. Brattleboro
Barber Milling Co., Minneapolis, Minn. Essex Junction
Barber Milling Co., Minneapolis, Minn. Brattleboro
Big Diamond Mills Co., Minneapolis, Minn. Rutland
Wm. A. Coombes Milling Co., Coldwater,
Mich. So. Royalton
Commercial Milling Co., Detroit, Mich. Proctorsville
Duluth-Superior Milling Co., Duluth, Minn. Brattleboro
Moseley & Morley Milling Co., Rochester,
N. Y. Rutland
Moseley & Morley Milling Co., Rochester,
N. Y. Bennington
Niagara Falls Milling Co., Niagara Falls,
N. Y. Essex Junction
Northwestern Consolidated Milling Co.,
Minneapolis, Minn. Poultney
New Prague Flouring Mills Co., New
Prague, Minn. So. Royalton, Brattleboro
Pillsbury Flour Mills, Minneapolis, Minn. Middlebury
Russell-Miller Co., Minneapolis, Minn. Rutland
Saskatchewan Flour Mills Co., Moose Jaw,
Sask. Brattleboro
Gwinn Milling Co., Columbus, O. St. Johnsbury
Tennant and Hoyt Co., Lake City, Minn. Barton
Geo. Urban Milling Co., Buffalo, N. Y. Wallingford
Valley City Mill'g Co., Grand Rapids, Mich. Cavendish
Washburn Mills, Buffalo, N. Y. Lyndonville

BRAND NAME	ANALYSES							GUARANTIES		
	Molsture	Crude ash	Crude protein	Crude fiber	Nitrogen-free extract matter	Ether extract	Selling prices	Crude protein	Crude fiber	Ether extract

WHEAT OFFALS

Brans—Continued

Wheat bran is the coarse outer coating of the wheat kernel.

Pure,	6.93	6.70	17.75	9.08	53.62	5.92	—	14.5	11.	4.
	7.80	6.33	18.19	9.00	53.56	5.12	—	13.	11.	4.
Am. Co.,	8.50	7.10	17.78	8.37	53.81	4.44	\$30	14.	9.5	3.
Pure Flakes	8.44	6.55	17.56	8.62	53.64	5.19	28	13.	10.	4.
Pure Flakes,	8.33	6.69	17.31	9.25	53.04	5.38	—	13.	10.	4.
Pure Flakes,	7.46	7.50	17.22	8.42	53.79	5.61	28	13.	10.	4.
Big Diamond,	8.36	7.08	16.44	9.16	54.17	4.79	29	12.8	11.07	4.5
Winter,	8.00	4.42	16.25	7.99	58.55	4.79	—	14.	—	3.
Henkel's	7.96	6.18	17.13	9.38	54.84	4.51	28-30	14.	12.	3.
Duluth Imp.,	7.82	7.55	15.81	9.62	54.35	4.85	29-30	14.5	11.	4.
Pure Una'd,	7.65	6.56	17.31	9.12	56.23	3.13	29	—	—	—
Choice,	7.88	6.24	16.88	8.45	55.43	5.12	30	—	—	—
Niag. Falls,	7.52	6.97	15.90	10.49	54.45	4.67	29	—	—	—
Pure,	7.44	6.83	16.88	8.91	54.88	5.06	30	14.5	11.	4.
Seal of Minn.,	7.34	7.64	16.13	9.75	54.17	4.97	28	13.5	12.05	4.
Unadult'd,	7.09	7.19	16.44	10.14	53.98	5.16	28.50	14.5	11.	4.
							-31			
—	8.53	7.30	16.69	8.68	53.96	4.84	29	13.	11.	4.
Robin Hood,	8.09	5.81	18.00	9.14	53.67	5.29	29	16.25	9.80	5.20
	7.93	6.12	16.69	8.00	57.40	3.86	—	15.	—	4.
Pure,	8.12	7.26	16.69	9.65	52.97	5.31	29	13.	13.	4.
	8.07	6.87	16.25	9.26	54.63	4.92	—	15.	11.5	4.
Choice,	8.48	6.65	16.35	8.19	55.83	4.50	29	17.75	10.93	—
Hard Coarse,	7.33	7.31	15.90	10.31	53.83	5.32	26.50	14.5	11.	4
							-30			

NAME AND ADDRESS
OF
MANUFACTURER OR JOBBER

SAMPLED AT

MIDDLINGS

See statements concerning analyses and values,
pages 115-116, 116-120.

Barber Milling Co., Minneapolis, Minn...Vergennes
Washburn-Crosby Co., Minneapolis, Minn.Montpeller

Red Wing Milling Co., Red Wing, Minn..Manchester
Washburn-Crosby Co., Minneapolis, Minn.Randolph
Allen Baker Corn Co., St. Louis, Mo.....Poultney
Brooks Elevator Co., Minneapolis, Minn.St. Albans
Northwestern Consolidated Milling Co.,
Minneapolis, Minn.Rutland

Pillsbury Flour Mills, Minneapolis, Minn.Brattleboro
Russell Milling Co., Albany, N. Y.....Randolph
David Stott, Detroit, Mich.Rutland
Valley City Mill'g Co., Grand Rapids, Mich. Lyndonville

Bill Bell & Co., Ogdensburg, N. Y.....Bristol

MIXED FEEDS

See statements concerning analyses and values,
pages 115-116, 116-120.

American Milling Co., Detroit, Mich.....Bristol

Commercial Milling Co., Detroit, Mich...Proctorsville
Duluth-Superior Milling Co., Duluth, Minn.St. Johnsbury, Burlington
Federal Milling Co., Mifflinsburg, Pa....Richmond
Garland Milling Co., Greensburg, Ind....Brattleboro
Great Western Cereal Co., Chicago, Ill...Bellows Falls
Hunter-Robinson-Wenz Milling Co., St.
Louis, Mo.Orleans
Kempter Mill and Elevator Co., Kansas
City, Mo.Rutland, Middlebury

BRAND NAME	ANALYSES							GUARANTIES		
	Moisture	Crude ash	Crude protein	Crude fiber	Nitrogen-free extract matter	Ether extract	Selling prices	Crude protein	Crude fiber	Ether extract

MIDDLINGS

Wheat middlings are:

(1) White middlings, that part of the offal from wheat left after separating it from the bran and the "shorts" or standard middlings; essentially a low grade flour, lower in feeding value than the reddog.

(2) Standard middlings ("shorts"); the coating of the wheat kernel just below the bran layer, the fine particles and fragments of bran, and flour particles.

Fancy,	9.39	2.48	18.44	1.47	64.37	3.85	\$37	18.	4.	5.
Adrain,	8.58	3.33	18.63	2.31	62.03	5.12	34.50	17.	4.	5.
							-37			
Bixota Flour,	9.21	4.52	20.19	4.18	56.21	5.69	34-35	18.	4.	5.
Stand. Lib'y	8.79	4.84	17.13	7.85	56.25	5.14	31-32	15.	8.	4.
Fancy White,	8.66	4.53	17.75	6.12	58.06	4.88	—	15.75	—	4.
Puritan,	8.29	5.08	17.56	6.68	57.13	5.26	29.25	14.	5.	3.
							-33			
Pure,	7.74	5.25	17.13	8.05	56.22	5.61	29.50	15.	10.	4.5
							-34			
B.,	8.18	5.78	16.25	8.12	56.52	5.15	31-33	15.	8.	4.5
Standard,	8.24	5.13	17.13	6.98	56.78	5.74	32	15.	8.	4.
Pennant,	7.54	4.53	17.13	5.76	59.90	5.14	32	17.	—	5.5
Choice,	7.79	5.06	17.13	6.03	59.09	4.90	31.50	16.8	6.	5.
							-35			
Shorts,	8.23	5.44	18.44	6.51	56.46	4.92	32	—	—	—

MIXED FEEDS

Wheat mixed feed is a mixture of the by-products from the wheat kernel.

Waumbeck,	7.98	4.44	16.64	5.33	60.91	4.70	\$32	17.06	7.41	4.03
Henkel's										
Co. Brown,	8.52	4.63	16.25	5.60	59.84	5.16	31	15.	7.	4.
Boston,	7.82	5.12	17.56	7.41	56.54	5.55	31-32	16.	8.5	4.5
Lucky,	8.43	5.17	17.31	7.55	56.38	5.16	31	14.	10.	4.
Garland,	7.63	5.93	17.31	7.70	56.95	4.48	30	15.25	8.5	3.75
Dairy,	6.83	9.14	17.75	11.12	51.85	3.31	30	15.	11.	3.
Sunshine,	7.37	5.87	16.69	7.74	57.66	4.67	30	14.5	8.	4.
Crescent,	7.24	5.76	17.75	7.79	56.89	4.57	32	16.	5.	4.

NAME AND ADDRESS
OF
MANUFACTURER OR JOBBER

SAMPLED AT

MIXED FEEDS—*Continued*

Milwaukee Grain and Feed Co., Milwaukee, Wis. Brandon
National Milling Co., Indianapolis, Ind. Rutland, Montpelier
N. E. Flouring Co. Randolph
Northwestern Consolidated Milling Co.,
Minneapolis, Minn. Brattleboro
Northwestern Consolidated Milling Co.,
Minneapolis, Minn. Rutland, Burlington, Pittsford
Northwest Mills Co., Winona, Minn. Chester
Pillsbury Flour Mills, Minneapolis, Minn. Waterbury, Manchester, Proctorsville
Pillsbury Flour Mills, Minneapolis, Minn. Middlebury, Winooski
Portland Milling Co., Portland, Mich. Randolph
Quaker Oats Co., Chicago, Ill. Rutland, Burlington
Red Wing Mill Co., Red Wing, Minn. Williamstown
Russell Flouring Co., Albany, N. Y. Barre
Russell-Miller Co., Minneapolis, Minn. Rutland, Burlington, Montpelier
Sheffield-King Milling Co., Minneapolis. So. Royalton
Sparks Milling Co., Terre Haute, Ind. Putney
Sparks Milling Co., Terre Haute, Ind. Brattleboro
St. Albans Grain Co., St. Albans, Vt. Windsor, Waterbury
F. W. Stock & Son, Hillsdale, Mich. Essex Junction, Randolph
Geo. Tileston Milling Co., St. Cloud, Minn. Lyndonville
Valley City Milling Co., Grand Rapids, Middlebury, Cavendish, Lyndonville
Mich. donville
Waggoner-Gates Mill Co. Bradford
Williams Bros. Co., Kent, O. Montpelier
E. S. Woodworth & Co., Minneapolis. Rutland, Manchester
Stock & Sons, Iola, Mich. Brandon, Randolph

Everett-Augenbaugh & Co., Waseca, Minn. Barre

MISCELLANEOUS

See statements concerning analyses and values,
pages 115-116, 116-120.

..... Bennington
..... Wallingford
W. G. Crocker, Minneapolis, Minn. Middlebury
W. G. Crocker, Minneapolis, Minn. Rutland

BRAND NAME	ANALYSES							GUARANTIES		
	Moisture	Crude ash	Crude protein	Crude fiber	Nitrogen-free extract matter	Ether extract	Selling prices	Crude protein	Crude fiber	Ether extract

MIXED FEEDS—*Continued*

XXX, Osota,	9.90 7.56	6.60 4.74	16.68 18.00	9.40 6.96	54.57 57.92	2.85 4.82	— 30 -31.50	17.5 17.	10. 8.	2. 4.5
Powerful,	6.93	6.21	18.00	7.71	56.34	4.81	32	14.	8.5	3.
—	7.89	5.54	17.56	6.83	56.94	5.24	35	15.	10.	4.5
XXX Comet,	7.75	3.13	18.88	1.93	63.08	5.23	34-36	16.5	3.	4.
Empire,	7.50	4.18	15.81	4.45	64.52	3.54	32	15.	10.	3.
XX Daisy,	8.24	3.37	19.06	2.41	62.10	4.82	35-36	18.	4.	4.
Fancy,	7.81	4.74	18.00	5.93	58.53	4.99	32	16.	8.	4.5
Champion,	7.19	5.61	16.44	6.91	59.23	4.62	32	14.87	7.55	—
Buckeye,	7.11	5.99	16.44	8.53	56.92	5.01	31-33	13.	8.	4.
Go-Far,	7.12	5.59	17.31	8.15	56.17	5.66	30	15.5	8.5	4.1
Regular,	7.96	5.62	17.75	7.49	55.88	5.30	32	15.	10.	4.5
Occident,	7.66	5.60	18.19	7.86	56.15	4.54	30-32	15.	10.	4.5
Gold Mine,	8.16	5.65	16.69	7.27	57.14	5.09	33	15.	8.	4.
Wabash,	7.84	6.20	17.13	6.92	57.46	4.45	32	14	8.	3.5
Try Me,	8.50	6.06	18.00	7.09	55.81	4.54	30	16	8.	4.5
H. G.,	7.69	5.61	17.31	7.57	56.86	4.96	32-33	16.	—	4.
Superior,	8.40	4.42	17.31	5.66	59.85	4.36	32	—	—	—
Waumbeck,	7.46	5.43	17.31	7.13	56.98	5.69	32	15.	9.	4.5
Farmers'										
Fav'te Cow,	6.94	5.49	17.13	6.38	58.99	5.07	30-32	14.79	7.50	4.25
Winter Cow,	7.25	6.35	17.13	6.56	57.86	4.85	32	15.	9.	4.
Mill Run,	7.80	5.81	17.75	6.46	57.70	4.48	32	1.5	15.	2.
Snow's,	7.32	5.98	17.56	7.89	55.57	5.68	32	14.	11.	4.
Monarch,	8.34	6.20	17.88	7.94	54.26	5.38	30-32	—	—	—
E.A.Co.Winged										
Home,	8.35	7.22	16.44	9.78	53.24	4.97	32	14.	12.	3.

MISCELLANEOUS

Reddog is a low grade wheat flour containing the finer particles of bran which cannot be separated in the process of milling.

Screenings are the smaller, imperfect grains, weed seeds, and other foreign materials having feeding values, which are separated in cleaning the grain.

Screenings,	9.41	2.85	14.69	3.70	66.27	3.08	31	—	—	—
Screenings,	8.83	4.62	16.69	6.51	59.14	4.21	—	—	—	—
Red Dog Fl'r,	7.99	4.43	19.50	3.37	58.79	5.92	37	17.	4.	5.
Red Dog Fl'r,	8.17	3.83	19.06	3.61	59.54	5.79	34-38	17.	4.	5.

WHEAT OFFALS

CARRYING BETWEEN 15 AND 16 PERCENT PROTEIN

MANUFACTURER OR JOBBER

BRAND

BRANS

Duluth-Superior Milling Co., Duluth, Minn.....Duluth Imperial
 Kehlor Milling Co., St. Louis, Mo.....Sixty
 Niagara Falls Milling Co., Niagara Falls, N. Y. Niagara Falls
 Washburn-Crosby Co., Minneapolis, Minn.....Hard-Coarse

MIDDINGS

MIXED FEEDS

Northwest Mills, Winona, Minn.....Empire

CARRYING BETWEEN 16 AND 17 PERCENT PROTEIN

BRANS

Big Diamond Milling Co., Minneapolis, Minn...Big Diamond
 W. A. Coombes Milling Co., Coldwater, Mich...Winter
 Lake of the Woods Milling Co., Ontario.....Canadian
 Moseley & Morley Milling Co., Rochester, N. Y. Choice
 Northwestern Consolidated Milling Co., Minne-
 apolis, Minn.Pure
 New Prague Flouring Mill Co., New Prague,
 Minn.Seal of Minnesota
 Pillsbury Flour Mills, Minneapolis, Minn.....Pillsbury's Unadul't'd
 Russell-Miller Co., Minneapolis, Minn.....
 Gwinn Milling Co., Columbus, Ohio.....
 David Stott, Detroit, Mich.Spring
 David Stott, Detroit, Mich.Winter
 Tennant & Hoyt Co., Lake City, Minn.....Pure
 Geo. Urban Milling Co., Buffalo, N. Y.....
 Valley City Milling Co., Grand Rapids, Mich...Winter
 Voight Milling Co., Grand Rapids, Mich.....Winter

MIDDINGS

Bill, Bell & Co., Ogdensburg, N. Y.....White
 Pillsbury Flour Mills, Minneapolis, Minn.....B
 Pillsbury Flour Mills, Minneapolis, Minn.....

MIXED FEEDS

American Milling Co., Detroit, Mich.....Waumbeck
 Commercial Milling Co., Detroit, Mich.....Henkel's Coarse Brown
 C. M. Cox Co., Boston, Mass.....Wirthmore
 W. A. Coombes Milling Co., Coldwater, Mich.....
 Hunter-Robinson-Wenz Milling Co., St. Louis,
 Mo.Sunshine
 Milwaukee Grain & Feed Co., Milwaukee, Wis...XXX
 Niagara Falls Milling Co., Niagara Falls, N. Y..Perfect
 Portland Milling Co., Portland, Mich.....Champion
 Quaker Oats Co., Chicagô, Ill.....Buckeye

MANUFACTURER OR JOBBER

BRAND

Lexington Roller Mills Co., Lexington, Ky.....	Thoroughbred
Sheffield King Mill Co., Minneapolis, Minn.....	Gold Mine
Stratton & Co., Concord, N. H.....	Honest
Voight Milling Co., Grand Rapids, Mich.....	Volght's Winter-Cow
Commercial Milling Co., Detroit, Mich.....	Henkel's Fine White

CARRYING BETWEEN 17 AND 18 PERCENT PROTEIN

BRANS

Amendt Milling Co., Detroit, Mich.....	Ames
Barber Milling Co., Minneapolis, Minn.....	Pure Flaker
Commercial Milling Co., Detroit, Mich.....	Henkel's
B. A. Eckhart Milling Co., Chicago, Ill.....	Pure
Federal Milling Co., Mifflinsburg, Pa.....	Lucky
Moseley & Morley Milling Co., Rochester, N. Y.....	Pure Unadulterated
.....	(L) (K)

MIDDLINGS

Washburn-Crosby Co., Minneapolis, Minn.....	Standard
Allen Baker Corn Co., St. Louis, Mo.....	Liberty Fancy White
.....	Pure
Brooks Elevator Co., Minneapolis, Minn.....	Puritan
C. M. Cox Co., Boston, Mass.....	Wirthmore
Hennepin Milling Co., Minneapolis, Minn.....	Ben Hur
Northwestern Consolidated Milling Co., Minneapolis, Minn.	Pure
Pillsbury Flour Mills, Minneapolis, Minn.....	A
Washburn Mills, Buffalo, N. Y.....	Pure Hard Wheat St'd
Russell-Miller Co., Minneapolis, Minn.....	Red Dog
Russell-Miller Co., Minneapolis, Minn.....	Standard
David Stott, Detroit, Mich.	Pennant
Valley City Milling Co., Grand Rapids, Mich....	Choice
Northwestern Consolidated Milling Co., Minneapolis, Minn.	Bran and Middlings
F. W. Stock & Sons, Iola, Mich.....	Monarch Middlings
Ashley & Blanchard, Windsor, Vt.....	Fancy
Ashley & Blanchard, Windsor, Vt.....	Fancy Winter
Duluth-Superior Milling Co., Duluth, Minn....	Boston
Detroit Milling Co., Detroit, Mich.....	Adrian
Federal Milling Co., Mifflinsburg, Pa.....	Lucky
Garland Milling Co., Greensburg, Ind.....	Garland
Great Western Cereal Co., Chicago, Ill.....	Daisy
Griswold & MacKinnon, St. Johnsbury, Vt....	Extra Good
Kemper Mill and Elevator Co., Kansas City, Mo.....	Crescent
National Milling Co., Toledo, Ohio.....	Pennant
Northwestern Consolidated Milling Co., Minneapolis, Minn. ....	.....
Red Wing Milling Co., Red Wing, Minn.....	Go-Far
Lexington Roller Mills Co., Lexington, Ky....	Pure
Russell Flouring Co., Albany, N. Y.....	Regular
Sheffield King Milling Co., Minneapolis, Minn....	Gold Mine
Sparks Milling Co., Terre Haute, Ind.....	Wabash
St. Albans Grain Co., St. Albans, Vt.....	High Grade

MANUFACTURER OR JOBBER

BRAND

F. W. Stock & Sons, Hillsdale, Mich.....	Superior
David Stott, Detroit, Mich.	Honest
Geo. Tileston Milling Co., St. Cloud, Minn.....	Waumbeck
J. G. Turnbull Co., Orleans, Vt.....	Creamery
Valley City Milling Co., Grand Rapids, Mich...	Farmers' Favorite
Waggoner-Gates Mill Co., Independence, Mo...	Mill Run
Williams Bros. Co., Kent, Ohio.....	Kent
E. S. Woodworth & Co., Minneapolis, Minn....	Snow's

MIXED FEEDS

CARRYING BETWEEN 18 AND 19 PERCENT PROTEIN

BRANS

Oakes Flour Mills, Oakes, No. Dak.....	
Saskatchewan Flour Mills Co., Moose Jaw, Sask.	Robin Hood

MIDDINGS

Barber Milling Co., Minneapolis, Minn.....	Fancy Low Grade
Washburn Mills, Buffalo, N. Y.....	Adrian
Washburn Mills, Buffalo, N. Y.....	Flour
Atlas Flour Mills, Milwaukee, Wis.....	Atlas Extra Flour
Detroit Milling Co., Detroit, Mich.....	Apex Winter
Duluth-Superior Milling Co., Duluth, Minn....	White
Pillsbury Flour Mills, Minneapolis, Minn.....	Daisy
Roller Mills Co., New Ulm, Minn.	
Geo. Tileston Milling Co., St. Cloud, Minn.....	Fancy
Bill, Bell & Co., Ogdensburg, N. Y.....	Shorts

MIXED FEEDS

National Milling Co., Indianapolis, Ind.....	Osota
N. E. Flouring Co.	Powerful
Northwestern Consolidated Milling Co., Minne-	
apolis, Minn.	XXX Comet
Pillsbury Flour Mills, Minneapolis, Minn.....	Fancy
Russell-Miller Co., Minneapolis, Minn.....	Occident
Sparks Milling Co., Terre Haute, Ind.....	Try Me
Stratton & Co., Concord, N. H.....	Tally Ho

CARRYING OVER 19 PERCENT PROTEIN

MIDDINGS

Red Wing Milling Co., Red Wing, Minn.....	Bixota Flour
Barber Milling Co., Minneapolis, Minn.....	Pure
Commander Mill Co., Minneapolis, Minn.....	Flour
La Grange Mills, Red Wing, Minn.....	Fine
Washburn Mills, Buffalo, N. Y.....	Flour

MIXED FEEDS

Northwestern Consolidated Milling Co., Minne-	
apolis, Minn.	Planet
Pillsbury Flour Mills, Minneapolis, Minn.....	XX Daisy

III. DISCUSSION OF THE RESULTS OF INSPECTION

Cottonseed meal: (See definition and analyses, pages 78-79). Twelve lots were examined, all of which maintained their protein guaranties within the established one percent limit. Two brands were somewhat deficient in protein, nearly reaching the dead line, but no stress is laid upon these shortages. One brand—the American Cotton Oil Company's "Choice"—lacked one percent of its fat guaranty; and five brands contained more crude fiber than their jobbers claimed for them, two of which—Humphreys, Godwin Co.'s "Dixie," and the Buckeye Cotton Oil Co.'s "Buckeye"—contained much more crude fiber than they should. The law calls for a guaranty of the maximum percentage of crude fiber, but permits the omission of the statements if the claimed contents do not exceed ten percent. Not only do the fiber contents of these two brands exceed ten percent, but they exceed the maximum guaranties made for them by 2.5 and 3 percents respectively; or, to rephrase the matter, one of these brands contained a third more, and the other two-fifths more fiber than their jobbers promised that they should contain. It is significant to note that these two brands carry the lowest protein guaranties, and, likewise, the least protein contents of the dozen brands listed in the table. This is evidently cause and effect or, in other words, "there's a reason." They maintained their protein guaranties, but their purveyors have not increased their crude fiber guaranties sufficiently, in view of the amount of fiber which was left in, or placed in, the goods. There is a strong tendency nowadays on the part of some cotton oil mills to increase to the limit the fiber content of the cottonseed meal by admixing therewith ground cottonseed hulls. The fact that there has been no checking up of this matter in the past in Vermont may in part explain these two episodes. In view of past inadequate inspections, there

¹ It should be noted that crude fiber is a relatively undesirable food ingredient; that the less there is in a feed the better, provided other nutrients replace it. Hence, unlike protein and fat, an excess over guaranty is decried rather than a deficiency.

was no reason on the part of jobbers to fear that their failures to maintain crude fiber guaranties would be noted.

Cottonseed meal is rich in both protein and fat and is relatively low in fiber, provided extraneous hulls are not designedly admixed therewith or untoward weather conditions do not render it impossible thoroughly to remove the hulls. It is universally regarded as the acme of feeding stuffs and, especially in view of present high prices for all sorts of grain feeds, should be used, in moderation, in every dairy ration. Even at the high prices at which cottonseed meal has sold in Vermont, this last winter, averaging \$33 or more, it is much the most economical source of digestible protein now upon the market. Pound for pound it furnishes about half as much again of digestible protein as does gluten feed, and about three times as much as wheat bran. The differences in prices between these materials are but slight. One should not assume, however, that, because it is the cheapest, cottonseed meal should be made the sole grain feed.

Cottonseed feed meal: (See definition and analyses, pages 78-79). Three brands of cottonseed feed meal were found upon the Vermont market, all of which met their guaranties. A ton cost on the average only about \$3 less than a ton of straight cottonseed meal. They carry on the average 24 percent protein, whereas the cottonseed meal carried over 41 percent. $41 - 24 = 17$. $17 \times 20 = 340$. This means that if one pays three dollars more for the meal than he pays for the feed, he gets for his three dollars 340 pounds more protein. The following statement shows the composition of the average cottonseed meal and of the average cottonseed feed meal as determined in the inspection reported in this bulletin:

	Water	Ash	Pro- tein	Fiber	Nitrogen- free extract matter	Fat
Meal	7.9	6.7	41.2	8.6	27.1	8.5
"Feed meal"	8.5	5.1	24.0	20.4	36.2	5.8
Meal contains more than the feed in percent..		1.6	17.2			2.7
Feed contains more than the meal in percent.....	0.6			11.8	9.1	
Meal contains more than feed in pounds per ton.....		32	344			54
Feed contains more than meal in pounds per ton.....	12			236	182	

It seems incredible that any Vermont dairyman would choose a feeding stuff of this sort, heavily laden with ground cottonseed hulls, in the place of cottonseed meal. There is more digestible protein in 1,200 pounds of the cottonseed meal costing \$20, than in a ton of cottonseed feed meal costing \$30; and there is 800 pounds less feed to haul. The extra \$10 is a high price to pay for 300 pounds more of relatively indigestible crude fiber and 400 pounds more of nitrogen-free extract matter. Vermont farmers can raise these on their own farms, and place them in their cows' mangers for much less than \$10. There is no question as to the legality of the sale of such cottonseed feed meals as were offered in Vermont this last winter. They were up to guaranty in every particular, but are not on this account advisable purchases. Whether guaranties are or are not maintained, so long as it is sold at present prices, Vermont farmers will do well to let cottonseed feed meal alone.

The similarity of the trade name of these goods, which is deemed by feed control officials to be a misnomer, to that of cottonseed meal, has perhaps led uninformed buyers to think that they were getting the straight meal. A glance at the label is sufficient to determine this point.

Linseed meal: (See definition and analyses, pp. 80-81). Five lots were sampled. They met their guaranties in all respects, save that one lot, unnamed—the product of the American Linseed

Co.—carried 1.5 percent more fiber than its maximum guaranty, or a fourth more than it was said to carry. The linseed meals as a class far exceeded their protein guaranty statements. Even at the extremely high prices at which they were selling last winter, they were, as they have always been, most admirable materials—indeed not relatively uneconomical—for dairy feeding purposes. They were far better purchases at \$42 than were some of the cheaper, widely advertised and more widely used feeds at much lower figures.

Linomcal: (See analyses, pages 80-81). This material is new upon the Vermont markets. It maintains its guaranty in all respects. It appears to consist mostly of ground flax screenings, intermixed with ground flax refuse, shives, etc. There seems some reason to think that this may be a close relative to "flax feed," or "flax flakes," characterized in former publications. It differs therefrom, however, in being apparently thoroughly ground.

Gluten feeds: (See definition and analyses, pp. 80-81). Eight brands were sampled, all of which maintained guaranties. A very slight shortage was noted in one brand, but it is too small to stress. In bygone years gluten feeds were quite apt to fail to make good their protein promises but for some time now they have been beyond reproach in this respect. Certain brands in the past, moreover, have been colored yellow, a custom which is now less commonly practiced. Gluten feed sold this past winter for from \$32 to \$33. It is rich in protein and fat, though lacking in ash, is light and flaky in character, well adapted to dairy feeding and highly esteemed for that purpose by the generality of feeders.

Corn oil meal: (See definition and analyses, pp. 80-81). These goods have not been found on sale of late. They are, or used to be, a by-product of the extraction of corn oil from the germ of the corn kernel. The guaranties were maintained, and at the price asked—\$29.50—the goods were fairly economical sources of food nutrients. Corn germ meal is less well known

than gluten feed, and is an uncommon visitor in Vermont markets; but it is a thoroughly satisfactory feed which, however, should be fed in moderation, as its excessive use may tend to affect the hardness of the butter.

Distillers' dried grains: (See definition and analyses, pp. 82-83). Six of the eight samples met their protein guaranties within 1 percent. Time was when distillers' dried grains were prone to fail to make good their protein promises, but they have steadied down in this respect of late. There now seems, however, reason to question their fat and fiber contents. The situation is essentially as follows:

Ajax flakes: 1 percent low in protein; 1 percent low in fat. Fourex grains: 1 percent low in protein; 0.5 percent low in fat. Climax grains: failure to guarantee the fiber content, which is relatively high. Extragood: failure to guarantee the fiber content. Imperial corn: failure to guarantee the fiber content, which is comparatively high. Empire State Dairy Feed: 1 percent less fat than is guaranteed. Husted: 1.25 percent more fiber than is guaranteed.

Distillers' dried grains are notably, and perhaps naturally, somewhat uneven in composition, and no great stress is laid upon these deficiencies. There appears to be no attempt to defraud in any case. It may be well, however, for the manufacturers to attempt to better the standardization of ingredients other than the protein.

Distillers' dried grains are valuable feeds, rich in protein and fat, of excellent mechanical character and in every way desirable. Extended trials at this station as well as elsewhere have convinced the writer that they have few, if any, superiors in the feed market.

Brewers' dried grains: (See definition and analyses, pp. 82-83). Four samples of grains and one of sprouts were tested. All met their protein guaranties, but every one failed to meet its fat guaranty, and in every case by a wide margin. Two of the brewers' grains samples decidedly exceeded the crude

fiber maximum guaranties, as did also the malt sprouts. It would appear that the suggestion just made concerning the necessity of the standardization of the composition of distillers' dried grains holds likewise for brewers' dried grains. Protein standardization is satisfactory; that of the fiber and fat is not.

At the prices which brewers' dried grains were offered in Vermont last winter, \$28 to \$31, they were attractive concentrates. Though not quite as high in protein as the distillers' grains, they sell at a lower price and are quite as good bargains. They are dry, bulky, and in every respect highly desirable feeds. Malt sprouts are not as a rule readily eaten by the cattle, unless they are moistened prior to use. They are a good feed and well worth using.

Proprietary dairy feeds: (See definition and analyses, pp. 82-83). Seven lots were sampled. One lot of the Quaker Oats Co.'s Blue Ribbon Dairy Feed was seriously below its guaranty in protein and was not guaranteed in either fat or fiber contents though the latter are well above the limit. Both brands of the Wirthmore goods were short in fat. The Perfection goods should be guaranteed in fiber, if the content is to be 10 percent or more.

A number of this class of goods carry upon their tags a statement of the ingredients of which they are composed. This is not required by the Vermont law, but it doubtless will be required in the near future. The statements made for a few of these goods is shown herewith.

Union Grains.—Distillers' dried grains, cottonseed meal, old process linseed meal, wheat middlings, wheat bran, hominy meal, malt sprouts, and $\frac{3}{4}$ percent of salt.

Unicorn Dairy Ration.—Distillers' dried grains, cottonseed meal, hominy meal, wheat or corn, gluten feed, barley feed and sprouts, wheat bran; guaranteed free from salt, molasses, screenings, or weed seeds.

Wirthmore Balanced Ration.—Cottonseed meal, gluten feed, malt sprouts, distillers' dried grains, wheat bran, hominy, corn meal.

Paragon Dairy Feed.—Cottonseed meal, gluten feed, barley by-product, and salt.

The statements made above appear to be borne out by the facts; that is to say the goods as found on the market appear to be as certified.

Proprietary feeds may or may not be worth while. They are necessarily unstandardized and their composition and make-up subject to the interests or whims of the manufacturer. The advisability of their purchase will naturally depend largely upon the prices at which they sell. It not infrequently happens that unmixed feeds may be bought at lower prices than the mixture; for, obviously, the mixer must be paid for the mixing. So far as can be determined the several mixtures are well made, their ingredients are standard materials, and their adaptations to the purpose for which they are designed are beyond criticism.

Corn and oat feeds: (See definition and analyses, pp. 84-85). Fifteen samples were analyzed, two of which were not guaranteed. Not a single case of shortage in protein or fat, or of excess over guaranty of fiber, was found. Four of the goods that were guaranteed as to their protein and fat contents were not guaranteed as to their fiber contents, but did not need this statement in view of the fact the law exempts from the necessity of fiber guaranty, goods which carry less than 10 percent of that ingredient.

The fact that guaranties were maintained should not be construed as testifying to the high grade of these feeds, or to the superlative character of their ingredients. The statement simply means that each manufacturer kept his promises—no more, no less. He may have promised but little, and, indeed, in some cases did promise very little; and these promises such as they were have been kept. These goods ranged in price all the way from \$28.50 to the absurd price of \$40, an average of \$32.50, a price quite out of proportion to feeding values, at any rate for dairy purposes. These goods as a class usually contain considerable amounts of rather inferior by-products, particularly oat hulls,

and, often, small amounts of some of the high grade protein concentrates, which are used to grade them up and to make them more saleable. These goods, together with the molasses feeds, are doubtless the most widely advertised of any that are offered to the Vermont trade. They are usually sold under trade names in the construction of which terms are often used which tend to create the impression that the materials are highly desirable purchases. Just as in the fertilizer trade, grandiloquent names are apt to be used to help sell the lower graded goods, so is it in the feed trade. These materials are in no sense balanced rations, nor are they well adapted to the feeding of dairy cows. If sweet, clean, and wholesome, they may prove a fair substitute for oats in the feeding of horses, particularly when corn and oats rule as high as they do today. If used for the feeding of dairy cattle, they should always be fortified with some of the proteinous concentrates, like cottonseed meal, gluten meal, brewers' or distillers' grains, etc.

The fiber contents of this class of goods as a whole tend to run lower than in previous years. It is evident that the feed inspection work in the various states has served to some extent to remedy a situation which in the earlier days justly caused severe criticism.

Several of these brands carry on their tags a statement of the ingredients of which they are composed. This is not required in Vermont, but is valuable information which doubtless will be required by the next revision of the law. The statements made for a few of the goods appearing in this bulletin, as made on sales in Vermont or nearby states within a year or so, are as follows:

Schumaker Stock feed.—Corn, oat meal by-products (oat shorts, oat hulls, and oat middlings), wheat flour, barley, 50 pounds cottonseed meal per ton, and $\frac{1}{2}$ percent salt.

Victor Feed.—Corn, oatmeal mill by-products (oat shorts, oat hulls, and oat middlings), and $\frac{1}{2}$ percent salt.

Molasses feeds: (See analyses and definition, pp. 84-85). Ten samples were drawn, all of which met their protein guar-

anties. Two failed to meet their fat guaranties, and several were above—some decidedly above—their fiber guaranties. One brand carried over 14 percent fiber. It should be remembered in this connection that excess over fiber guaranty is to be regretted, rather than welcomed. It would seem as if there was need of standardization of the fiber content of these feeds.

Molasses feeds as a class have been looked upon in the past with suspicion, but are now a better and safer feed than formerly. Their extremely undesirable, viable weed seed contents of a few years ago have been largely eliminated, and the danger then so serious is greatly lessened. However, as a class they are not usually advisable purchases, because of their relatively low grade and the likelihood of their inferior make-up. Quite recently a few high protein goods have been placed on sale, into the composition of which it is impossible for large amounts of inferior material to enter. The generality of them contain—as their labels declare in states where more modern laws exist than obtain in Vermont—light grains and grain by-products, low grade by-products, crop residues, grain screenings, molasses, salt, together with some high grade concentrate used to “fatten up” the protein percentage, as well as to improve the character of the mixture. The grain screenings usually are so treated by grinding or by heat as to lessen or destroy their viability, a treatment not originally accorded these products. The low grade by-products and crop residues if offered in an unmixed condition would have little or no sale. Their food nutrient contents and their digestibilities are not enhanced by mixing with other ingredients. To use a simile: the fact that, we will say, a lot of sawdust is mixed with a meat and potato hash and the mixture placed on a boarding house table for eating, neither increases the food value nor the digestibility of the sawdust; it is sawdust still. Similarly with molasses feeds, oat feeds and the like. These low grade by-products and crop residues, may be made somewhat more palatable, and, hence, more edible, and be more readily eaten because of the admixture, particularly with the waste molasses; but they

really contain no more actual digestible food nutrients than they carried in the unmixed condition.

Manufacturers of molasses and oat feeds sometimes speciously argue as to the necessity of the "conservation" of these low grade materials. They argue that the feeding stuff trade is a logical outlet for low grade products, and that it is in the interests of economy to admit such into the feeding stuffs market. This point of view is fairly well expressed in two letters recently received from a milling concern located outside of New England. The first (accurately quoted) reads as follows:

"Will you kindly advise us your judgment regarding the use of oat hulls, either re-ground or not, in combination with heavy feeds, considering the matter from both an economic and feeding standpoint. What we wish to learn we can perhaps best bring out by stating our theory of the matter, which is as follows:

To prepare oats for human food, the meat of the oat alone can be utilized. That this meat of the oat can be replaced with by-products such as hominy feed, gluten feed, cottonseed meal, corn meal, etc., producing a feed as high or higher in protein than the whole oats; but in themselves too highly concentrated or too heavy to give the best feeding results, without the addition of the oat hulls. That the use of the oat hulls conserves the feed resources of the country in utilizing a product which would otherwise be waste, and that the addition of the hulls when honestly and intelligently used, is an actual benefit in lightening up the heavy feeds, making them more bulky and more easily digested; the benefits obtained in feeding being similar in nature to the benefit derived in grinding corn and cob meal together.

We fully appreciate that this practice might be abused by unscrupulous dealers in the use of too large proportions of the hulls, but we are anxious to know if our theory is correct or not, provided only enough hulls are used to lighten up the feed."

To this letter the following answer was made:

"Replying to yours of the 6th, would say that I can see no reason, either economic or otherwise, justifying the use of extraneous oat hulls in any feed; that is to say, looking at the matter from the standpoint of the purchaser of the feed. The fact that plenty of farmers are using the high grade concentrates you mention and lightening them up with materials that are much more economical to use than are oat hulls, some of them farm grown products, constitutes a perfect answer to your proposition."

The second letter (accurately quoted) reads as follows:

"Referring to yours of the 8th replying to ours of the 6th relating to the use of oat hulls in the composition of feed; while we recognize that there is an opportunity for dishonest practices in the use of oat hulls, our theory as outlined in our former letter was based on the assumption of the honest use of the hulls for the lightening up of concentrated feeds and the feeds sold for exactly what they are.

We believe that it is a well recognized fact that the matter of conserving the feed resources of the country is a matter of great importance, particularly to the consumers, and the question which is of interest to us is if the by-products of cereal mills cannot be utilized to advantage in making up feeds for live stock, what legitimate use can be made of the hulls to avoid their being an absolute waste which would result in corresponding increase in the price of cereal products.

We are very much interested in this subject and will appreciate the benefit of your opinion."

and was answered as shown below:

"In reply to yours of the 20th, would say that I cannot agree with you that it is of importance to me, a consumer, that oat hulls be conserved at some point several hundred miles away from me, and shipped to me by freight, I to pay the freight rates on several different railroads, when I have got on my own farm materials as digestible, that have been raised at a relatively low price; indeed,

materials containing a larger amount of digestible nutrients than are in the hulls."

The correspondence stopped at this point.

Molasses feeds sold last December at widely variable prices, ranging from \$24 to \$34, and averaging about \$28.50. These figures were enough lower than the prices asked for the higher graded concentrates as well as for straight grain goods, to make them quite attractive. If sold at prices commensurate with their actual values, molasses feeds as now made may well be worth using. As a whole they have decidedly improved in composition, and particularly, as has already been remarked, by the exclusion, or destruction, of most if not all of the weed seeds with which they were formerly laden. Many of them now bear upon their labels a statement of their composition, in order to comply with the laws of other states, statements such as appear below, and made on sales in nearby states within recent years. The purchaser who reads such a tag can, if he will, inform himself as to the materials which it is claimed enter into the composition of the feeds.

Quaker Dairy Molasses Feed.—Cottonseed meal, grain screenings, flax pods and stocks, oat meal mill by-products (oat hulls, oat middlings, and oat shorts), corn and molasses.

Sucrenc Dairy Feed.—Cottonseed meal, oats, barley, wheat, malt sprouts, molasses and mixed broken grains from wheat, oats, buckwheat and barley grain screenings, and $\frac{1}{2}$ percent salt. These were identified and from a "trace" to "considerable amounts" of weed seeds were also identified, as sold in Pennsylvania in 1910.

Husted Molasses Feed.—Cottonseed meal, gluten, oat clippings, corn, oil meal, molasses, and $\frac{3}{4}$ percent salt.

Sugarota Dairy Feed.—Cottonseed meal, flax bran, linseed meal, malt sprouts, mill feeds, molasses and salt. Found as sold in Pennsylvania in 1910, "cottonseed meal, flax plant refuse and shives, linseed meal, malt sprouts, corn, oats, wheat, barley, molasses, salt, and a small amount of weed seeds."

Sugarine Dairy Feed.—Cottonseed meal, oats, barley, wheat, grain screenings, malt sprouts, molasses, and $\frac{1}{2}$ percent salt. As sold in Pennsylvania in 1910, the findings are "as certified" with statement that weed seeds from "small" to "considerable amounts" were found.

Miscellany: (See definitions and analyses, pp. 86-89). Three calf meals met the protein guaranties which their manufacturers made for them, but two were quite lacking in fat. They are intended as whole or partial substitutes for milk in the feeding of young calves. There seems no reason, either from their chemical composition, from their appearance, or from the statement made by the manufacturers as to their composition as shown below, to question but what they will serve this purpose, although doubtless they are not thoroughly well adapted to the feeding of dairy calves at the very outset.

These foods were certified elsewhere to contain:

Schumaker Calf Meal.—Oat meal, wheat meal, ground flax seed and casein. Found to be "as certified" as sold in Pennsylvania in 1910.

Blatchford's Calf Meal.—Locust bean meal, wheat flour, flax seed, cottonseed meal, peas, beans and lentils. Found to be "as certified" as sold in Pennsylvania in 1910. Some salt was found.

Dried beet pulp: Four samples of dried beet plup, one containing molasses and three without this admixture, were tested. They met their guaranty statements in all respects. The sale of these goods appears to be on the increase in New England. The material should be moistened before feeding. It affords a fairly satisfactory, but uneconomical, substitute for silage or roots. Although classified among the concentrates in the inspection, dried beet pulp should hardly be so regarded. There seems no good reason why any Vermont farmer, who has an ample supply of corn silage, should contemplate its purchase. Close to the factories doubtless beet pulp may be well worth while, but it is not an economical purchase at this distance.

Hominy: One unguaranteed sample of hominy was found—the product of the Buffalo Cereal Co.—which seems to be of normal grade.

Alfalfa: A sample of ground alfalfa, unsponsored and unguaranteed, seems fairly normal.

Cornmeal, provenders, rye and buckwheat products: (See definitions and analyses, pages 86-87). A dozen samples of provenders were found to be beyond reproach. Five samples of corn meal were apparently of good grade. Samples of rye feed, rye middlings and buckwheat bran proved normal in character. Rye by-products are not usually considered as satisfactory feeding stuffs as the parallel wheat products and have not afforded as good returns in experimental feeding trials. Buckwheat by-products are highly variable in quality. The middlings are extremely satisfactory feeding stuffs, but the hulls are of little use. The “bran” may be any admixture of the two in any proportions.

Poultry feeds: (See definition and analyses, pages 88-91). These feeds are classified in the table as animal meals, meat scraps, etc., scratch feeds, chick and growing feeds, and mashes. The animal meals, barring a single sample of the Burlington Rendering Company's bone and meat, met guaranties in all respects. The scratch feeds were similarly up to guaranty. The guaranty statement made on one brand, the product of E. T. and H. K. Ide of St. Johnsbury, is illegal, in that it combines the protein and fat guaranties in one. The results attained in the analyses of the chick and growing feeds, however, were less satisfactory. The Wirthmore growing feed lacks protein and fat; the Purity growing feed is similarly lacking; the Park and Pollard chick feeds and growing feeds are short in their fat contents; and the Husted chick feed is unguaranteed. The Purity mash is lacking both in protein and fat; the Model Milling Company's egg mash, and W. R. White's mash are unguaranteed; the Federal feed contains considerable more fiber than is guaranteed; and Page's perfected and Park and Pollard's fattening

feed, less fat than are guarantied. The sampling agents report no guaranty on some of the Page goods.

Certain of these goods were certified in New York to contain:

Amco Hen Feed.—Corn, wheat, barley, kaffir corn, linseed oil cake, sunflower seed and buckwheat.

Bowker's Animal Meal.—Cooked meat and bone.

Swift's Lowell Cooked Meat Scraps.—Beef scraps.

Darling's Beef Meal.—Animal meal.

Queen Poultry Mash.—Corn meal, wheat bran, wheat middlings, alfalfa, beef meal, corn cob.

H. O. Algrane Scratching Feed.—Wheat, wheat screenings, oats, cracked corn, kaffir corn, milo maize, buckwheat, sunflower seed.

Husted Chick Feed.—Corn, cut oat meal, cracked wheat, kaffir corn, peas, millet.

Park and Pollard Co.'s Dry Mash.—Bran, middlings, corn, wheat, barley, alfalfa, fish, meat, bone and salt.

Park and Pollard Growing Feed.—Bran, middlings, corn, wheat, barley, alfalfa, fish, meat, bone and salt.

Quaker Oat Co.'s American Poultry Food.—Corn, barley, wheat bran, cottonseed meal, oat hulls.

Model Mill Co.'s Egg Mash.—Corn meal, middlings, wheat meal, bran, gluten feed, oil meal, malt sprouts, pea meal, alfalfa, animal meal, ground screenings, cottonseed meal, salt.

Wheat offals: (See definitions and analyses, pp. 92-100). The wheat offals were found in good shape. About 120 different analyses were made, and only 5 of the 120 carried less than 15 percent protein. There seems no reason to question the character of a single one of the wheat offals found on sale in Vermont last winter. Complete analyses, however, were made of a considerable number of these goods as shown on pages 92-97. A large share of them were guarantied in accordance with the laws of other states, and, with rare exceptions, main-

tained their guaranties. Guaranties are not called for in Vermont, hence no question is raised concerning the few failures.

Bran, because of its protein and fat contents, and because of its mechanical characteristics, is considered a valuable feeding stuff, perhaps over-rated, certainly a luxury at present (March, 1912) high prices, but, notwithstanding, a standard and highly desirable feed. Middlings are rich in digestible protein and fat and an excellent feed, although costly at present prices. Mixed feed, if free from objectionable offal impurities, which may be worked off more readily under this guise than when either bran or middlings are sold as such, is a desirable though costly material. Red dog at ruling prices ranks well with middlings and quite equals their feeding values. Screenings are worth considering for hens or sheep, but when sold in mixtures besmeared with molasses are to be decried.

CLASSIFICATION OF FEEDING STUFFS

The feeding stuffs offered for sale in Vermont may be classified in a general way as follows, the classification being based on their average protein contents as determined in recent inspection analyses:

1. *Forty percent protein and more.* Cottonseed meals, meat meals for poultry.
2. *Thirty to forty percent protein.* Linseed meals, distillers' dried grains.
3. *Twenty to thirty percent protein.* Gluten feeds, brewers' dried grains, malt sprouts, corn oil meal, cottonseed feed meals, proprietary dairy feeds, certain molasses feeds, calf meals.
4. *Fifteen to twenty percent protein.* Wheat offals (brans, middlings, mixed feeds, red dog flour, screenings), molasses feeds, rye offals (feed, middlings), certain chick feeds and poultry mashers, alfalfa meal.
5. *Nine to twelve percent protein.* Corn and oat feeds, provenders, corn meal, hominy, scratch feeds for poultry, certain chick feeds and poultry mashers.

6. *Nine percent and less protein.* Dried beet pulp.

One should remember that a classification is a man-made affair; not a rule, but a guide; not mandatory, but suggestive; that protein is a dominant but not the sole food nutrient to be taken into account in feed selection; and finally, that considerations other than mere chemical composition should have weight in the choice. But when all is said and done, the protein content of the foods should be an important factor in the determination of a choice and is never to be overlooked or minimized.

AVERAGE COMPOSITION OF FEEDS SAMPLED AND ANALYZED IN THE WINTER OF 1911-12, AVERAGE PRICES AND NUMBER OF POUNDS OF PROTEIN AND FAT BOUGHT FOR A DOLLAR

					A dollar bought	
	Protein, lbs.	Fiber, lbs.	Fat, lbs.	Cost, \$	Protein lbs.	Fat, lbs.
CLASS 1						
Cottonseed meal	41.2	8.6	8.5	\$33	25.	5.2
Meat meals (poultry)	48.4	..	11.7	45	21.5	5.2
<i>Average pounds protein and fat for a dollar (class 1) ..</i>					23.3	5.2
CLASS 2						
Linseed meals	36.9	7.5	6.6	\$41.50	17.8	3.2
Distillers' dried grains	30.4	10.9	12.2	32	19.	9.6
<i>Average pounds protein and fat for a dollar (class 2) ..</i>					18.4	6.4
CLASS 3						
Gluten feeds	26.3	6.6	3.1	\$32.50	16.2	1.9
Brewers' dried grains	26.6	14.7	4.5	29.50	18.1	3.1
Malt sprouts	25.9	12.7	1.6	..	..	..
Corn oil meal	21.1	8.7	8.4	29.50	14.2	5.7
Cottonseed feed meal	24.	20.4	5.7	30	16.	3.8
Proprietary dairy feeds	25.5	9.7	5.6	32	15.9	3.5
Certain molasses feeds	24.	9.5	4.6	31.50	15.2	2.9
Calf meals	23.5	4.3	5.7	65	7.2	1.9
<i>Average pounds protein and fat for a dollar (class 3, exclusive of calf meals)</i>					16.0	3.5

AVERAGE COMPOSITION OF FEEDS—*Continued*

					A dollar bought	
	Protein, lbs.	Fiber, lbs.	Fat, lbs.	Cost, \$	Protein lbs.	Fat, lbs.
CLASS 4						
Wheat brans	16.7	9.1	4.8	\$29	11.5	3.3
Wheat middlings	17.7	5.8	5.1	33	10.7	3.1
Wheat mixed feeds	17.4	7.	4.8	31.50	11.1	3.
Red dog flour	19.3	3.5	5.8	35.50	10.9	3.3
Screenings	15.6	5.1	3.6	31	10.1	2.3
Molasses feeds	17.1	13.1	4.5	27	12.7	3.4
Rye offals	17.4	4.6	3.4	31	11.3	2.2
Alfalfa	14.7	31.7	1.3	32	9.2	0.8
Certain chick feeds	14.9	3.1	3.6	43.50	6.8	1.7
Certain poultry feeds	20.2	8.4	4.2	43	9.4	2.
<i>Average pounds protein and fat for a dollar (class 4, exclusive of chick feeds)</i>					10.8	2.6
CLASS 5						
Corn and oat feeds	10.	8.1	4.7	\$32.50	6.2	2.9
Provenders	11.	4.1	3.9	36.50	6.	2.1
Corn meal	9.8	2.	4.1	34	5.8	2.4
Hominy	9.5	3.6	7.2	..	..	..
Scratch feeds	11.5	2.8	3.3	40.50	5.7	1.6
Certain chick feeds	12.	1.9	3.2	42	5.7	1.5
Certain poultry feeds	13.2	5.7	3.6	38	6.9	1.9
<i>Average pounds protein and fat for a dollar (class 5) ..</i>					6.0	2.0
CLASS 6						
Dried beet pulp	8.9	18.7	0.6	\$27.50	6.5	0.4
<i>Pounds protein and fat for a dollar (class 6)</i>					6.5	0.4

ADULTERANTS AND DILUENTS USED IN FEEDING STUFFS

The high prices which have obtained of late in the feed trade have led to the use by some compounders of feeding stuffs of materials low both in price and in food values. The average analyses of some of the materials used to debase feeding stuffs appear in the following table. It is not to be inferred that these are all in use today and all found in Vermont used feeds; but it is notorious that all have been used and that most of them are still in evidence to a greater or less extent.

	Moisture	Ash	Protein	Fiber	Nitrogen-free extract matter	Fat
Cob meal	6.8	1.7	2.2	31.2	57.7	0.4
Oat clippings	11.0	14.7	12.8	18.6	39.8	3.1
Oat hulls	7.3	6.2	2.6	32.3	50.8	0.8
Wheat screenings	10.2	3.3	12.9	7.4	63.7	2.5
Grain and seed screenings.....	7.1	21.1	11.3	9.2	46.9	4.4
Weed seeds	10.0	4.2	13.3	11.6	53.9	7.0
Flax bran	7.4	5.7	6.0	41.8	34.9	4.3
Flaxseed screenings	9.8	7.0	14.9	14.0	41.6	12.7
Cottonseed hulls	8.5	2.3	3.7	44.5	39.5	1.5
Rice hulls	8.0	17.4	2.7	33.5	37.8	0.6
Peanut hulls	6.6	2.1	5.5	70.9	13.7	1.2

Nine of these materials have been found present in feeding stuffs as sold in Vermont, even by the superficial inspection which the meagre appropriation permits. Some are still being used. Some have to be declared upon the tag or stencil which each bag carries. Would it not be worth while to amend the Vermont laws so as to require a full statement by the manufacturer in plain and unmistakable terms as to the ingredients he uses in compounding his feeds, this to appear on each package, as is required by the laws of several states and by the proposed uniform feed law adopted by the Association of Feed Control Officials?

The New York and the Kentucky Stations call attention to a hitherto unappreciated admixture of sand in certain compounded feeds which are sold in those states, some of which, it may be remarked, are likewise sold in Vermont. The silica and sand contents found in these goods range from 1.25 to 3.91 percents. Sand is not a normal constituent of any uncompounded concentrate. Oat clippings, as sold, may carry from 6 to 9 percent and screenings, as sold, from 2 to 3 percent. The Bible queries as to the substitution of stone for bread; and the replacement of 4 pounds of feed in a sack by an equivalent weight of sand inevitably suggests the Biblical utterance. Manufacturers have claimed that these cases are sporadic, occasional, accidental, "isolated cases of an extreme character"; but it is interesting to

note that 9 out of 10 samples of a certain brand as found on sale in Kentucky carried excessive amounts of sand. In other words, the "accidents" were 9 times as common as were the normal occurrences. This brand is sold in Vermont. It is guaranteed—in Kentucky—to contain 20 percent of grain screenings. It is silent in Vermont as to this matter, because, unlike Kentucky, Vermont does not require manufacturers to disclose such matters. No other of its guaranteed ingredients, all of which are "straight-feeds," should carry more than traces of sand. Several samples of grain screenings as reported in the Kentucky bulletin carried from 2½ to 7 percent of "dirt, sand, straw, sticks," etc. One sample carried 14.6 percent, another 51.6 percent.

These two stations comment conservatively on the matter as follows:

"It is evident that it would be unsafe to assert in any one case that sand was deliberately introduced into the mixture as such, but the figures do show that a generous amount of dirt, of which sand is a constituent, becomes incorporated into certain refuses that form a part of certain brands of cattle foods. In those cases where sand is declared to be present careful microscopic or mechanical examinations were made, the testimony of which is positive. The statement of the fact is a sufficient comment on the quality of certain refuses now used in the manufacture of commercial cattle foods."¹

"In some samples more than 3% of sand was found. In others the analyses showed only a few tenths of one percent, indicating that the samples were free from sand adulterations. The feeds in which we found the higher amount of sand were mixed feeds containing finely ground materials and masked in other ways, and they were found to contain various amounts of screenings, weed seeds, etc. This would seem to indicate that the sand had found its way into the feed by the use of sweepings and screenings, and probably not by the intentional addition of sand. * * * * *

¹ N. Y. (State) Sta. Bul. 340, pp. 294-5 (1911).

tionally or not, it is evident and the fact remains that such materials should not be in feeding stuffs in appreciable quantities, at least."²

WHAT THE LAW HAS DONE

Has the law been worth while? What has it accomplished?

Its enforcement costs the state \$500 a year. It has been a factor in bringing about the following desirable changes in the situation which obtained prior to the entry of the 1900's:

(1) The statement on each feeding stuff package of its chemical composition, showing its content of food nutrients.

(2) The statement on many feeding stuff packages of the nature of the ingredients of which the goods contained therein are made.

(3) The requirement that the statements made by the manufacturers on the tags or stencils be lived up to in fact, with publicity in the foreground and prosecution in the background in case of failure to make good the self-imposed standards.

(4) The declaration of adulteration in clear terms on every package and, in many cases, of inferiority.

(5) The emancipation of the honest manufacturer from dishonest competition, in that more than was previously the case goods are sold for what they are rather than for what they seem to be.

(6) The withdrawal or lessened sale of very low graded goods; the upgrading of many brands.

(7) The promotion of intelligent buying. The feeder buys better than formerly. He has a clearer understanding as to food nutrients, as to what his stock needs, why they need it and where he can best get it. The guaranty which stares him in the face on every bag, the station publications, the educational campaign, has taught him something as to the economics of feed purchase.

The law can be and will be improved; there is yet much to be done; but the situation as compared with that obtaining in the late nineties, when adulteration was rife, is greatly bettered.

² Ky. Sta. Bul. 156, p. 9 (1911).

IV. CONDIMENTAL FEEDS

The Vermont law includes within the definition of "concentrated commercial food stuffs," as given in Section 4983 P. S., the "condimental stock and poultry foods, proprietary or trade marked stock and poultry foods." Little attention has been paid for nearly ten years to the condimentals, the last statement concerning them having been made in bulletin 104, issued in December, 1903. It seemed worth while to survey this trade again, and, consequently, sixteen samples of this class of goods were taken by the sampling agents last winter, were analyzed and are reported on pages 124-125. Furthermore the law authorizes the director to include in the feeding stuffs inspection bulletins "information in relation to the character, composition, value and use" of feeding stuffs. In view of the many inquiries received touching this class of material it is clear that information will be pertinent.

The chemical analyses of the brands reported on pages 124-125 were made from the standpoint of their feeding values and have no bearing whatsoever on their medicinal properties. The various brands were highly unlike each other in respect to their chemical composition, some carrying as little as 3 percent protein and few as high as 15 percent thereof. All contained relatively high ash contents, three of the brands carrying approximately 50 percent thereof. Irregularity in composition is to be expected, in view of the fact that this class of goods is not in the least standardized, as is the case with most regular feed stuffs.

Condimental and medicinal stock and poultry foods as a class carry drugs, herbs or condiments, and fillers or diluents. The more common fillers used are such everyday feed stuffs as the several wheat offals (brans, middlings, mixed feeds, grain screenings, etc.), linseed meal, flaxseed meal, cottonseed meal, etc., as well as the hulls of the seeds of mustard, beans and peas, and flax plant refuse, shives, etc.; the more common drugs used include gentian, ginger, copperas, Epsom salts, Glauber's salts,

salt peter, antimony sulphid, sulphur, charcoal; the more common herbs are fenugreek and anise; and the more common condiments, pepper, salt and mustard. The poultry foods are also apt to carry ground bone, grit, venetian red and hematite.

Most of the sixteen brands included in this inspection have been tested by stations in other states where, with ample funds, more thorough work has been possible than at the Vermont station. Some of these stations have published in connection with the analyses of these goods a list of the ingredients which were claimed by the manufacturers to be present in accordance with the terms of the several laws, or which were identified with the microscope in the course of inspection. The presence of many of the ingredients shown below as found at the various stations indicated has been confirmed by the work done in connection with the present inspection on goods bearing the same or similar names. The somewhat superficial survey of the other materials seems to indicate the presence of the ingredients stated.

It is not claimed that every ingredient which possibly may be present in a given "feed" is included in the following statement. This is particularly true of the data furnished by Vermont observations which were necessarily superficial. All that is claimed for the statements is that the materials named were identified in the samples under examination, and that they appeared, as a rule, to make up the bulk thereof. So far as the applicability of the data thus secured to Vermont conditions in 1911 is concerned, it should be remarked that the mixing formulas in use a few years ago may have been changed since that time and that for this reason the data derived from the publications of the other stations may not be entirely valid. Yet with one exception analytical results attained as late as 1911 are included in the statements. Furthermore, as has been previously pointed out, it may be said that a survey of the samples drawn by this station leads the writer to believe that the borrowed statements are in the main applicable to the goods as found on sale in Vermont in 1911.

NAME AND ADDRESS
OF
MANUFACTURER OR JOBBER

SAMPLED AT

CONDIMENTAL FOODS, ETC.

Capitol Food Co., Tiffin, O.....	Bellows Falls, Poultney
W. D. Carpenter Co., Syracuse, N. Y....	Putney
Drs. Hess & Clark, Ashland, O.....	Castleton, Marshfield, Brattleboro
International Stock Food Co., Minneapolis, Minn.	Barre, Manchester
Pastura Manufacturing Co., Elmira, N. Y.	Wallingford
Pratt Food Co., Philadelphia, Pa.....	Rutland, Bennington
Pratt Food Co., Philadelphia, Pa.....	Barre, Brandon
Security Remedy Co., Minneapolis, Minn.	Castleton
Security Stock Food Co., Minneapolis, Minn.	Barre, No. Bennington
Seneca Co., Tiffin, O.....	Wallingford
J. J. Fleck, Tiffin, O.....	Bradford
Drs. Hess & Clark, Ashland, O.....	Castleton, Brattleboro, Northfield
International Stock Food Co., Minneapolis, Minn.	Windsor, Barre, Manchester
Pratt Food Co., Philadelphia, Pa.....	Fair Haven, Rutland
Security Stock Food Co., Minneapolis, Minn.	Brattleboro, Barre
Capitol Food Co., Tiffin, O.....	Poultney

BRAND NAME					Nitrogen- free extract matter	Ether ex- tract
	Water	Ash	Protein	Fiber		
CONDIMENTAL FOODS, ETC.						
Capitol Stock Remedy.....	9.31	44.54	4.19	21.33	19.74	0.89
Nutriotone	7.67	11.13	20.81	8.68	46.34	5.37
Dr. Hess' Stock Food.....	5.54	35.12	11.81	5.11	40.83	1.59
International Stock Food..	5.50	25.50	9.63	10.89	44.71	3.77
Pastura.....	5.16	17.27	14.25	18.17	36.30	8.85
Animal Regulator	5.60	21.30	12.50	9.95	44.57	6.08
Conditioner	6.62	14.79	12.50	15.34	44.91	5.84
Security Stock Powder....	5.30	31.04	10.31	9.66	34.24	9.45
Security Calf Food.....	7.98	10.62	15.81	3.32	56.58	5.69
Seneca Stock Powder....	11.72	52.41	2.88	....	....	1.89
Poultry Food and Egg Pro- ducer	7.28	24.09	19.50	12.00	34.41	2.72
Hess' Poultry PanACeA...	6.31	45.39	9.88	4.04	33.32	1.06
International Poultry Food and Tonic	6.20	17.51	14.69	17.55	41.62	2.43
Pratt's Egg Producer.....	6.66	27.08	13.56	8.39	36.15	8.16
Security Poultry Food and Egg Maker	6.64	26.94	11.63	9.71	37.55	7.53
Capitol Poultry Remedy...	13.44	24.98	10.94	3.05	43.93	3.66

Capitol Stock Food, Capitol Stock Food Co., Tiffin, Ohio.—Wheat offals, anise seed, fenugreek, salt, Epsom salts, mustard, charcoal, pepper, cinnamon, sulphur. [Iowa Sta. Bul. 87 (1907); Wis. Sta. Bul. 151 (1907); Mass. Sta. Bul. 106 (1905)].

Nutriotone, W. D. Carpenter Co., Syracuse, N. Y.—Flaxseed meal, cottonseed meal, bean meal, wheat product, meat product, corn meal, salt, fenugreek, sulphur, charcoal. [Ind. Sta. Bul. 152 (1911); Mass. Sta. Bul. 106 (1905); R. I. Sta. Bul. 94 (1903); N. J. Sta. Bul. 184 (1905)].

Dr. Hess' Stock Food, Drs. Hess and Clark, Ashland, Ohio.—Wheat offals, linseed meal, bean or pea hulls, gentian, fenugreek, pepper, charcoal, salt, saltpeter, Glauber's salts, Epsom salts, gypsum, copperas. [Ind. Sta. Bul. 152 (1911); R. I. Sta. Bul. 94 (1903); Va. Sta. Bul. 144 (1903); Mass. Sta. Bul. 106 (1905); Iowa Sta. Bul. 87 (1907); Wis. Sta. Bul. 151 (1907)].

International Stock Food, International Stock Food Co., Minneapolis, Minn.—Wheat offals, flaxseed meal, gentian, pepper, ginger, charcoal, salt. [Ind. Sta. Bul. 152 (1911); Iowa Sta. Bul. 87 (1907); Wis. Sta. Bul. 151 (1907); N. J. Sta. Bul. 184 (1905); Va. Sta. Bul. 144 (1903); Penn. Sta. Bul. 70 (1905); R. I. Sta. Bul. 94 (1903)].

Pratt's Animal Regulator, Pratt Food Co., Philadelphia, Pa.—Wheat offals, anise, fenugreek, gentian, salt, ginger, corn meal, charcoal, Epsom salts. [Ind. Sta. Bul. 152 (1911); R. I. Sta. Bul. 94 (1903); N. J. Sta. Bul. 184 (1905); Va. Sta. Bul. 144 (1903); Mass. Sta. Bul. 106 (1905)].

Pratt's Conditioner, Pratt Food Co., Philadelphia, Pa.—Oil meal, wheat offal and salt. [Ind. Sta. Bul. 152 (1911)].

Security Stock Food (Security Food Co. or Security Stock Food Co., Minneapolis, Minn.) is reported by the Iowa station in 1907 and the Massachusetts station in 1905 as carrying wheat offals, salt, sulphur, venetian red and pepper and divers plant tissues. Most of these materials are readily recognizable in a brand now under survey and sold under a somewhat different name by a company the name of which is slightly altered.

Seneca Stock Powder.—The Seneca Horse Condition Powder was found in June, 1911, as sold in Indiana, to carry sulphur, Glauber's salts, Epsom salts, saltpeter, copperas, salt, sodium bicarbonate, charcoal and unidentified bark and seed coatings. Some of these were identified in the Stock Powder.

Fleck's Poultry Food and Egg Producer.—Fleck's Poultry Food as sold in Indiana in 1909 was found to carry Epsom salts, saltpeter, venetian red, pepper, sulphur, bone and Peruvian bark. Whether the present goods, with a somewhat different name, carries all these ingredients cannot be stated. Some of them were observed in the Vermont sample.

Hess' Poultry PanACEA.—Wheat bran, venetian red, gentian, salt, Glauber's salts, copperas and saltpeter. [Ind. Sta. Bul. 152 (1911)].

International Poultry Food and Tonic.—The International Poultry Food as sold in Indiana in 1911 was found to contain gentian, fenugreek, and probably some screenings. Whether the present goods, with a somewhat different name, carries all these ingredients cannot be stated. Some of them were observed in the Vermont sample.

Pratt's Egg Producer.—Wheat product, linseed meal, red pepper, sulphur, calcium carbonate, Glauber's salts, venetian red, gentian and wild seeds. [Indiana Station Bul. 152 (1911)].

The prices asked for relatively small packages of these materials are so high that they are expensive feeds, when used as such. Whether they are worth their cost as medicines is a question which, of course, must be answered by the individual buyer. No information is at hand as to the amount of money paid out by Vermont farmers for this class of goods. A survey made in Wisconsin some five years ago led to the conclusion that about \$300,000 annually was being paid out by Wisconsin farmers for condimental feeds. It is not unlikely that Vermont farmers buy proportionately as much.

The claims commonly made for such goods as are now under discussion are essentially as follows:

First, that they are appetizers, tending to promote and to improve digestion and, therefore, to increase production, be it work, flesh, milk, or wool.

Second, that they possess medicinal virtues.

Touching the first claim it may be said that there is no valid evidence to the effect that condiments or spices tend to increase the digestibility of any of the food nutrients or to increase production. On the contrary there is evidence which tends to prove that such is not the fact. As to the second claim, it may be remarked that the drugs which are commonly found present in the condimental foods are simple and well known remedies. Doubtless these are serviceable at times, and, in the quantities in which they are commonly present and ordinarily used, they are not likely to be in the least harmful. Yet one may express a reasonable doubt whether such mixtures, when used by non-professionals who are uninformed as to the nature and therapeutic properties of the drugs they are using, are as likely to prove effectual in cases of serious illness as the prescriptions of a skilled practitioner.

It is not easy to regard the claims made by some manufacturers in a serious frame of mind. It does not seem as if any intelligent man would give them credence. It were quite as rational to expect that one sovereign remedy would build up a "white man's hope" and at the same time control and cure rheumatism, earache, and clergyman's sore throat, as to look for increased milk in cows, faster speed in horses, more eggs laid by hens, and for the cure of glanders in horses, abortion in cows and scours in calves, as a result of the use of one and the same powder. Somewhat less stress is laid by most manufacturers today on their food properties than formerly and more stress on their medicinal properties. Yet a typical advertisement in the March, 1912, number of a prominent agricultural paper, one which fills the entire back cover page and which lies before the writer as he writes, uses the catch words, "Let me fatten 'em up," and states that the goods which the advertise-

ment vaunts "doubles the milk and butter, when fed to milch cows . . . fattens hogs and beef cattle for market in 40 days' less time . . . as an egg maker . . . doubles the egg supply."

Testimonials are not lacking as to the value of each and every one of these multitudinous products and as to their abilities to accomplish all that is claimed for them. These testimonials are of course written in thorough good faith, but they record impressions and opinions which are usually quite without basis in careful test or observation. Those who are well informed as to the difficulties which hedge about the accurate conduct of a feeding trial, and know how conservative one needs to be in the drawing of deductions therefrom, need not be told that conditions other than the use of these stock feeds were probably the true causes of the favorable results attained. Wherever careful experimental trials have been made under expert and disinterested supervision—and there have been a great many such made in this and other countries—the outcome has invariably shown that the use of condimental feeds as feeds was unprofitable and without material effect on production, whenever the animals to which the product was fed were at the outset in good healthy condition.

Careful studies made a few years ago at the Iowa station¹ show clearly that the great bulk of most stock foods—half or more—is made up of common everyday feeding stuffs; that one-tenth is salt and one-tenth charcoal, while three-tenths are made up of simple herbs, bark, roots, sulphur, Epsom and Glauber's salts and the like. The small proportions of drug, which occur in most mixtures, and the small doses offered—a tablespoonful or thereabouts—results in giving but a small fraction of the amount of the drugs which would be likely to be prescribed by a veterinarian. The conglomeration of drugs found in some of the mixtures is interesting. In some cases the materials used seem antagonistic, to possess opposing properties. Healthy animals are not in need of medicine. Such as are so

¹ Bul. 87 (1907).

ailing as to be poor producers should be treated with a drug adapted to the special abnormal condition, instead of being dosed with a mixture of herbs, condiments, drugs, cathartics and food stuffs, perhaps containing and perhaps not containing anything well adapted to meet the conditions which exist, a material claimed to be a panacea for all sorts and conditions of ills under all sorts and conditions of circumstances occurring in all sorts and kinds of farm stock.

Sometimes, however, an animal is slightly ailing, or is "off feed," hardly sick enough to necessitate a veterinarian's services. Under such circumstances stock foods or tonics may perhaps prove efficacious; but it is not essential that high priced proprietary condimental mixtures be used to remedy this situation. The feeder can buy the drugs at the drug store and formulate his own tonic, can save money by doing so, and can use definite quantities of definite materials rather than unknown proportions of a more or less mysterious, but usually diluted, mixture. The Maine¹ and the Iowa² stations have suggested drug mixtures that are worth considering. The Maine mixture costs but 20 cents a pound, is concentrated instead of diluted, is all drug and not mostly feed stuff, and, hence, far stronger. It is probably at least as efficient as, and certainly far cheaper than, the generality of condimental feeds. The Maine station suggests: Pulverized gentian, one pound; pulverized ginger, one quarter pound; pulverized saltpeter, one quarter pound; pulverized iron sulphate, one quarter pound. Mix; feed tablespoonful in feed once daily for ten days; omit three days; feed as above for ten days more.

The Iowa station suggests: "Fenugreek, 8 pounds; ginger, 8 pounds; powdered gentian, 8 pounds; powdered sulphur, 8 pounds; saltpeter, 8 pounds; resin, 8 pounds; cayenne pepper, 4 pounds; flaxseed meal, 44 pounds; charcoal, 20 pounds; common salt, 20 pounds; wheat bran, 100 pounds." It further says that "this mixture is so near the average stock food that neither the

¹ Me. Sta. Rpt. 12, p. 52 (1896).

² Iowa Sta. Bul. 87 (1907).

farmer nor stock could tell the difference"; that it should cost less than 5 cents a pound; that "a tablespoonful *would not* put his stock on the market in 30 days' less time, nor double the flow of milk, prevent cholera in hogs, abortion in cattle, roup in chickens, and glanders in horses," but that it would be "extremely inexpensive" and worthy of "as much credit in other ways as any of its class."

The Iowa station also suggests this simple mixture, the preceding one being offered apparently largely for the purpose of matching up the medley of materials usually employed by manufacturers for this purpose:

"Powdered gentian, 1 pound; powdered ginger, 1 pound; fenugreek, 5 pounds; common salt, 10 pounds; bran, 50 pounds; oil meal, 50 pounds."

"SELECTING FEEDS"¹

Bear in mind the following characteristics of each:

Alfalfa meal, more convenient to handle than hay, much easier to adulterate, price usually excessive, rich in protein.

Beet pulp, soaked up, a good substitute for silage or roots but higher priced.

Bran, (wheat) light, bulky, appetizing, high in mineral-matter, high in crude fiber. Relatively expensive at present prices.

Buckwheat, low in protein—usually pays to sell it and buy back the middlings.

Buckwheat middlings, heavy, usually economical source of protein, tend to make soft, oily butter.

Bulky feed, bran, gluten feed, distillers' grains, corn and cob meal.

Constipating, cottonseed meal, corn fodder and hay.

Corn, easily digested, usually cheapest source of energy. Pays to grind.

Corn and cob meal, bulky, considerable crude fiber, nearly equal to corn meal in ration because of bulky nature. Grinds fine.

Cottonseed meal, high in protein, heavy, should be fed with something else, makes for hard butter, relatively cheap source of protein, ordinarily should not constitute more than one-third of the mixture.

Distillers' dried grains, rich in protein, very variable in composition, bulky, must be fed with other feeds.

Dried brewers' corn grains, light, bulky, high in protein, not readily eaten alone.

Dried brewers' rye grains, similar in character to the corn grains. lower in digestible protein.

Gluten feed, rich in protein, should be fed with other grains. usually a desirable and economical source of protein.

¹ Penn. Sta. Bul. 144, p. 19 (1912).

Hominy chop, usually economical source of energy, low in protein, palatable, heavy. Good substitute for corn meal if needed.

Laxative, oil meal, bran slightly, silage, roots.

Molasses, a non-protein feed, good appetizer, usually too high priced for its food value.

Molasses feeds, usually high in waste materials; too high priced for their feed value.

Not palatable, gluten feed, brewers' and distillers' grains, cottonseed meal.

Oats, good feed, rich in mineral matter, high in crude fiber, not high enough in protein to use for balancing a ration, too expensive to feed at the past year's prices, good for calves, especially so if ground and hulls sifted out.

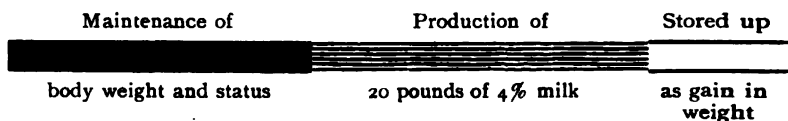
Proprietary feeds, usually variable in composition, frequently contain weed seeds and useless waste material, high in fiber and relatively expensive for the amount of energy furnished, save labor of mixing.

Roots, desirable substitute for silage, usually costs more to grow.

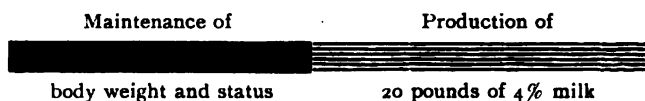
Silage, succulent, appetizing, economical, low in protein, should be fed after milking, a little hay or dry fodder should always be fed with it. One of the best farm grown feeds for milk products."

WHAT BECOMES OF THE FEED EATEN BY A 1000 POUND COW?

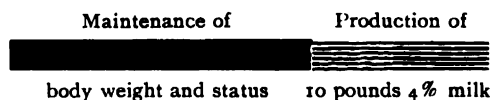
WHEN FED TOO MUCH



WHEN FED JUST ENOUGH



WHEN FED TOO LITTLE



From Penn. Sta. Bul. 114, p. 3. (1912)

UNIVERSITY OF VERMONT

AND STATE AGRICULTURAL COLLEGE

VERMONT AGRICULTURAL
EXPERIMENT STATION

BURLINGTON, VT.

BULLETIN No. 165

JUNE, 1912

The Peat and Muck Deposits of Vermont

- I. SUMMARY—Pages 141-142.
 - II. INTRODUCTION—Pages 142-144.
 - III. THE USES OF PEAT AND MUCK—Pages 144-176.
 - IV. CONCERNING THE VERMONT SURVEY—Pages 176-179.
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 - VIII. ANALYSES OF FORWARDED SAMPLES—Pages 234-240.
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✍ Copies of the reports and bulletins of the Station are sent free of charge to any address upon application.

✍ Address all communications not to individual officers but to the Experiment Station, Burlington, Vt.

Director's and State Forester's offices, chemical, horticultural and dairy laboratories are in Morrill Hall at the head of Main street; botanical and bacteriological laboratories are at Williams Science Hall, University Place; veterinary laboratories at 499 Main Street.

Experiment farm and buildings are on the Williston road, adjoining the University grounds on the east.

*In rationecoope with Bu. An. Ind., U. S. Dept. Agr.

BULLETIN 165: THE PEAT AND MUCK DEPOSITS OF VERMONT

By J. L. HILLS AND F. M. HOLLISTER¹

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NOTE.—During the preparation of the matter appearing on pages 144 to 176 on "The Uses of Peat and Muck," the writer made free use of several articles and monographs dealing with the subject, and especially of the recent (1911) bulletin of the National Bureau of Mines, entitled "The Uses of Peat for Fuel and Other Purposes."

¹Analytical work by Mr. Hollister, during his service as Assistant Chemist; discussion by the Director.

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Franklin, "	186 " 208, 236 " 226
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I. SUMMARY

Peat and muck are not the same thing, though the words are commonly used interchangeably. The former is a less disintegrated product than is the latter, which is often no more than a highly organic swampy soil. They are similarly formed, however, and intergrade. They are formed in wet and ill-drained areas from diverse aquatic and other plant growths and occur throughout the areas formerly altered by glacial action. Chemically they contain organic matter, nitrogen in varying quantities, and relatively little available mineral plant food. One peat may be mosslike in character; another, more truly a muck, may be a positive mud. They are dark hued, very absorbent, and of varying weight and density.

Peats are commonly used as fuel in other countries, occasionally in this country. An interesting account of Vermont usage of peat fuel is given on pages 158-162. It has many strong points in its favor and while not likely to displace coal and wood, is often worth using. Agriculturally it is used as a fertilizer and soil amendment, as a stable absorbent and litter, as a stock food, and in commercial fertilizer manufacture. Its service as a fertilizer and soil amendment and as a stable absorbent are well worth while, but its use as a stock food or as an ingredient of a commercial fertilizer is less commendable.

A survey of Vermont peat and muck deposits was made several years ago. Some 200 samples were drawn from all sections of the state and analyzed. The location and description of the more important deposits is given on pages 179 to 194, and full analyses showing the fertilizer and fuel values of 188 samples appear on pages 204 to 220. The general nature and properties of the several deposits are discussed by counties on pages 222 to 233. Among the more important large deposits may be mentioned those in and around Bristol pond and Shoreham swamp in Addison County; the 100 acre area in South Burlington, which is of high fuel but rather low fertilizing value; large deposits in Franklin,

Highgate and Richford in Franklin County of high value for fuel purposes; the large number of high grade deposits in Grand Isle County, particularly in Isle La Motte, North and South Hero; and the extensive area in the town of Stratton, Windham County. And "there are others."

II. INTRODUCTION

The peat and muck deposits of the United States form one of its latent and practically undeveloped resources. They stand in no need of "conservation"; they call for exploitation. They are under-used, are workable, are worthy of attention. The National Bureau of Mines, as well as several state geological and other surveys, have been investigating the extent and character of these deposits in various sections; private enterprises in this and other countries have expended large sums in the industry; and occasional local owners have made small use of their own bogs as a source of fuel or fertilizer. Broadly speaking, however, the deposits as a whole have been neglected in favor of coal, wood, and gas as fuels, and of barn yard manure or commercials as fertilizers. Believing that it were worth while to determine the existence and extent of these deposits within state borders, and to arouse Vermonters to their value, the Station several years ago instituted a survey, the results of which are set forth in this bulletin. Several reasons have conspired greatly to delay the completion of the study of the data and the issuance of the bulletin, which, in a partially finished condition, has been preserved, like peat, for future use. It was, and still is, thought by the writers that these deposits are of service in Vermont chiefly for agricultural purposes, although certain ones are doubtless capable of furnishing a satisfactory fuel. Attempts have been made in this survey to locate as many of the deposits known to the writers as possible, to ascertain their depth, area, and accessibility, and to obtain samples for analysis.

Practically no systematic effort has been hitherto made in Vermont to determine its peat resources. Miscellaneous samples of peat and muck have been forwarded by interested parties to the Station from time to time; but, taken as they have been by persons often unfamiliar as to adequate methods of sampling, their validity as representative of the deposits from which they were drawn is open to question. The analytical results attained on such samples have been published by the Station in several reports and bulletins. Specific reference to these is made in tables later on (pages 234-240).

Doubtless the threatened coal shortage caused by the miners' strike of 1902 gave impetus to the studies of the various peat deposits of the United States and Canada. The availability of many materials as substitutes for coal or for emergency usage has been canvassed, with a consensus of opinion in favor of peat as the most ubiquitous and serviceable material for this purpose. Much work has been done looking towards the development of economic methods of its excavation and preparation. Furthermore, the increasing scarcity of wood serviceable as fuel, as well as for other purposes, offers another reason justifying such a survey in Vermont, in view of the fact that wood is the chief or only fuel used on most Vermont farms. The high cost of coal and the long and heavy hauls from railroad stations militate against its large usage. Moreover, the known and available anthracite supplies are held by good authorities to be strictly limited and likely to be exhausted within the present century. While electricity and the heat of the interior of the globe doubtless will be made available in the future for the economic development of heat energy, that time has not as yet arrived. For all these reasons a survey of the peat resources of Vermont seems proper and expedient even in advance of the time of need.

However, as has already been remarked, the agricultural uses of peat are at present in Vermont more important than is its service as fuel. It has been a common practise in the past

on many Vermont farms, though less common to-day, usually between the periods of summer and fall harvests, to excavate muck or peat and either to spread it directly upon the soil as a top dressing, to pile it in heaps for use in composting with manure, or to use it as an absorbent in stables. Such usage might well be made to a greater extent than at present. It were better to employ time, effort and money in the getting of such material for more free usage in the stable to absorb urine, to lessen its fermentation, to extend the manure, than to spend money so freely for commercial fertilizers. The latter are well enough in their way; but it were better to husband home resources, to lessen waste, to utilize the plant food of farm origin. A penny saved is one earned. The prevalent wastage from fermentation and leaching of manure many times outweighs in commercial value that of the plant food purchased in commercial fertilizers. The usage of peat would go a long way towards lessening this loss. Again, there now lies locked up in Vermont's myriad peat bogs and muck beds thousands of tons of nitrogen which only await the spade and exposure to become more or less servicable in crop growth. This plant nutrient costs 19 cents or more a pound when bought in commercial fertilizers. The nitrogen of peat is not as active nor as readily available as is the nitrogen used in a good commercial fertilizer, although peat is at times used in the manufacture of that commodity, as is explained at considerable length on pages 172-174; but, since it is home supplied, it is less costly. If the issuance of the results of this survey serves to attract greater attention to this important source of home supplied nitrogen, it will have accomplished a very good purpose.

III. THE USES OF PEAT AND MUCK

It would seem proper, before the discussion of the results attained in this survey is entered upon on pages 176-240, to define what peat and muck are, to indicate in a general way their chemical and physical properties, the extent and distribution of

the deposits, and the method of their formation. This review is shown on pages 144-176 and includes, as a preliminary to the discussion of the analytical data displayed on pages 204-240, a description of the several uses of peat which are considered at some length, with special reference to what are conceived to be the possibilities under Vermont conditions.

WHAT IS PEAT AND WHAT IS MUCK?

The Vermont farmer is not apt to discriminate between peat and muck. He sometimes uses the words interchangeably, but more often does not know what peat is, applying the word muck to deposits which strictly are peaty in character. A distinction exists and should be made clear at the outset of this bulletin. Peat may be defined as the yellow brown to black, more or less fibrous residue of partially decomposed and disintegrated vegetable matter derived from mosses, sedges, and water plants in general, which has accumulated mostly under water, and, consequently, away from the air, under conditions which have served in part to arrest the ordinary processes of decomposition. Muck, on the other hand, is peat wherein the processes of decay have well nigh done their work, the fibrous structure being destroyed, the mass being of a black oozy character, the ingredients being somewhat more oxidized and, hence, to some extent made more available to plant growth. A muck, in farmer's parlance, is often simply a swampy soil of black hue and of a relatively high organic matter content.

It is more particularly to the effect of water that peat formation may be attributed. It excludes the air and largely precludes micro-organic growth, in that it favors the formation of soluble organic compounds which are thought somewhat to inhibit bacterial action. Hence peat forms only where there is either standing water or where saturation occurs. In view of the fact that muck, properly so-called, is simply a disintegrated peat, peat in its old age as it were, and that its service is mainly that

of a fertilizer, more stress will be laid in this bulletin on the discussion of peat than of muck, since, as has already been pointed out, it is muck in the making.

Drained bogs on which the surface moss has ceased to grow are said to be "dead." The peat therein undergoes a sort of ripening, a more complete decay, darkens in hue, becomes more highly compressed and its ash percentage increases, all this because of organic matter oxidation. It now resembles a black loam or mud and constitutes a true muck. Peat naturally tends thus to oxidize, as is shown by the rapidity with which it blackens when loosely piled and exposed to the air. The blacker and the more compact it is, the higher its fuel value. Such peat as a rule is found in wooded bogs. Muck is of higher value agriculturally than is peat, provided it is not too greatly reduced by soil admixture, and peat, which is low in ash, is of higher value as a fuel than is muck.

ORIGIN AND FORMATION OF PEAT

Peat forms only in those locations where the climatic and topographic conditions favor growth on the surface but slow and partial decay below the surface. These conditions are an ample rainfall, a humid atmosphere and preferably, but not necessarily, a moderately cool or cold temperature; and either basin-like depressions or gently sloping or flat areas which are poorly drained and, hence, waterlogged. Thanks to the work of the prehistoric glaciers, these conditions are met in many sections of New England, as well as of the northern portion of the United States. They are particularly well met in Canada where fully 35,000 square miles of land surface are covered by peat deposits, or thrice the similar area located within our borders. Large areas also occur in northern Europe and Asia wherever the ancient ice cap passed. Its causal relation to the imperfect drainage of vast tracts in the northern hemisphere of both countries, above the 40° parallel of latitude, to the large numbers of shallow, undrained basins (the many lakes and ponds of Quebec, On-

tario, northern New England, etc., such, for instance, in Vermont as Memphremagog, Caspian, Bomoseen, St. Catherine and the myriad small ponds that dot the landscape) and to such a broad, flat valley as that of Lake Champlain, has been developed in a previous bulletin of this station.¹

The chemical constituents of the original plant fibers were gathered mainly from the air. Were it not for the partial decay of the mature vegetation and the consequent liberation and return of the gaseous elements and compounds back to the atmosphere, immense deposits of peat would form. And such do form in Arctic regions where decay is very slow or non-existent. But in the temperate zone gaseous escape more nearly keeps pace with accumulation, and a century sees the formation of, perhaps, but a few inches of peat. In the warmer climates decay goes on too rapidly for peat formation, and peat as such does not exist. The tundras of Siberia and Alaska, the peat bogs of Ireland, the muskegs of Canada, are examples of peat formation under favorable conditions.

Obviously peat is made only in wet places, in locations where the ground is waterlogged or water hidden; conditions under which the air supply is limited, the water supply abundant, bacterial life not active and, hence, organic matter preserved rather than destroyed.

Many plant life types figure in peat formation. Thus in the water-filled basins, lakes, ponds, etc., wherein practically all Vermont peat is found, many aquatic plants flourish. One finds algae (pond scums), certain mosses which grow under the surface of the water, and diverse aquatic seed plants, which grow habitually under the water, some sending their flowers to the surface and others their leaves, stems and flowers above its surface. Among these may be mentioned pond weeds and lilies, bullrushes, sedges, water-grasses growing in the deeper waters, and a multitude of others more or less akin to these, which

¹ Vt. Sta. Bul. 143, pp. 230-236 (1909); see also Vt. Sta. Bul. 154, pp. 709-710 (1910) on the formation of cumulose (peat) soils in such basins.

grow where the water is more shallow or in times of drought is to some extent withdrawn. Some of these appear upon the floating marginal shelf or mat of turf which frequently rings about the center of a pond. Surrounding these one finds herbaceous and shrubby growths, particularly heaths and willows. Then comes the sphagnum, the peat moss, the distinctive peat forming plant, a greyish-green to white or sometimes red tinged growth, which possesses the peculiar property of growing continuously at the top while dying beneath. Sphagnum seldom rises more than three feet above the water level, is a very rapid grower, and, hence, a great maker of organic matter. Beyond these are found the conifers, more particularly the tamaracks, swamp spruces, cedars and, sometimes, pines and, perhaps, on the borders, deciduous trees.

Peat is of various origin in different parts of the world. Sphagnum moss is its almost sole constituent in Great Britain; together with sundry aquatics (lilies, sedges, grasses, rushes) and fallen leaves, its main component part as formed on this continent; while wild rice largely enters into the makeup of Eurasian peat.

According to local conditions of size, depth of basin, soil types, etc., the natural vegetation may differ. Thus we may have a bog which from an aeroplane might look all alike, or one which might look, according to topography, more or less like a target with a center of water and of water lilies, and concentric rings of bullrushes and sedges, shrubs and herbaceous plants, sphagnum, cedars and tamaracks.

Vermont bogs are more particularly of two sorts:

First, those formed by the closing in of the sphagnum growth which rings about a small pond, the so-called peripheral encroachment type, as shown, for example, at Bristol pond, Round pond in South Hero and at Sterling pond in Johnson.

Second, those formed by the gradual shallowing of the depressions.

The deposits are of two sorts, which might be termed "dead" and "living"; the one turfed over with grass, seeming often to be nothing more or less than meadow land, showing nothing of the characteristic bog growth, deposits, indeed, the very existence of which their lifetime owners do not suspect; the other where mosses are flourishing on its surface and the characteristic vegetation is evident. Most Vermont bogs are of this latter type and are locally called swamps, cranberry meadows, or beaver meadows. Passing from without inwards they carry pines, cedars, spruce, tamarack, ashes, alders, cattails, sedges, rushes and, of course, the ever present sphagnum.

The built-up plain, on which the water level is always below the surface of the peat but where it tends to rise through the years as plant residues collect, is not the type of peat deposit found to any extent in Vermont, it being the coastal plain and salt marsh type. Its peat is apt, however, to be of a more uniform character than that found in depressions or basins.

Davis¹ estimates that in the United States proper an area of 11,188 square miles is covered by peat deposits of a good quality. Assuming a 9 foot depth and 200 tons of salable fuel per acre foot, the total approximates 13,000,000,000 tons, an amount which could furnish heat and power for years to the entire nation. He further points out that Maine, back from the seacoast, New Hampshire (exclusive of the White mountain region), Vermont, (outside of its mountainous areas), Massachusetts (east of the Berkshires), practically all of New York state, Michigan, Wisconsin, Minnesota, and Florida, with parts of Indiana, Illinois and Iowa, are areas in which workable peat beds are common. He states that such occur but are less common in other regions, including the Green Mountain area in Vermont and the rest of New England not listed in the former category, as well as such other sections as the seacoast from Maine to Mexico, parts of Pennsylvania, Ohio, Indiana, Iowa

¹ "The Uses of Peat for Fuel and Other Purposes." U. S. Dept. Intr.; Bu. Mines; Bul. 16, pp. 12-13 (1911).

and the Dakotas. The workable deposits are mostly located in northern states, where fuel is most needed. No data are at hand which would warrant any estimate as to the total area of Vermont's deposits. Suffice it to say, however, that it is doubtless large, indeed ample, though probably less so proportioned to area than in many other states.

CHEMICAL COMPOSITION

Peat is formed from plant tissues which have become more or less decomposed, mainly as a result of the activities of sundry micro-organisms, more particularly bacteria and fungi, exerted under conditions not conducive to rapid destruction. Mechanical and chemical agencies are also operative, but are probably as a rule less important than are the biological factors. It contains both organic and inorganic material, the former and part of the latter being of plant origin, the latter being in part of water-formed or wind-blown calcareous matter or silt. It is made up mostly of the modified residues of the more resistant organic compounds of the plant growth from which it is formed, mainly the celluloses, and lignins, together with the resins and kindred bodies, insoluble nitrogenous compounds and mineral matters. The modifications result in the formation of soluble, insoluble and gaseous compounds, some simple, some complex. The soluble ones tinge and often acidify the water; the gases, mostly carbon dioxid, and methane (carbonic acid gas and marsh gas) escape; the insoluble woody and fibrous residues, which sometimes appear almost intact and sometimes are nearly devoid of structure, constitute what is known as peat.

The actual chemical makeup of the organic matter is but slightly understood, particularly as to the transition and decomposition products which occur. It is a heterogeneous admixture of substances, some known, some unknown, some guessed at, complex and doubtless highly variable. To list the many organic acids, more or less mythical in character, as well as the sundry organic compounds, and to mention the derivatives which are

obtained from dry distillation, would take many words. However, its elemental composition is the usual carbon, hydrogen, oxygen, nitrogen and a little sulphur in varying proportions. Ordinarily the more completely decomposed the peat, the more its carbon and nitrogen and the less its oxygen and hydrogen contents, for the reason that gas production consumes relatively less carbon than of oxygen and hydrogen.

A series of analyses reported by Johnson¹, displaying the chemical changes which occur as a result of the alteration of sphagnum into peat, shows successive increase of the carbon content from 40 to 62 percent, a sharp drop of the oxygen content from 42 in the light fibrous young peat to about 31 percent in the dense form, and no marked changes in the hydrogen or nitrogen contents.

Peat ash is a variable both in quantity and quality. The purest peats carry barely 3 percent and good ones rarely more than 10 percent ash, while some mucks of the lowest quality will contain as much as 90 percent, being simply a loamy soil. This mineral matter is in the one case of organic origin; in the other it is doubtless organic in part (plant and animal residues), but consists mostly of soil infiltrations or accumulations. These are either borne in by the water in suspension or in solution or are blown in by the winds. They are not strictly ash matter, i. e., are not of organic origin. Water-borne silts, as well as streams heavily laden with dissolved salts, contribute much ash to peat formations. The iron salts which occasionally are found, bog iron ores, marl beds, and the like, are evidences of water action. Dust accumulation is uncommon in this section.

So variable is the percentage of ash in peat that average statements mean but little. Johnson² furnishes the following data for minima, maxima and averages.

Potash	0.05%	3.6%	0.9%
Phosphoric acid ...	.....	6.3%	2.5%
Lime	4.7%	94.4%	24.0%

¹ Peat and its uses, p. 24 (1866).

² Loc. cit., pp. 47-49 (1866).

The carbon percentage, be it greater or less, and the calories of energy derived therefrom, are the determining factors as to fuel values; and the total organic matter content, the raw material from which humus may be made, and especially the nitrogen content, and to a very slight extent the potash, phosphoric acid and lime contents of the ash, are important on account of their fertilizing values.

PHYSICAL CHARACTERISTICS

Peat may vary in color from yellow brown to black, may be either light and fluffy in texture, fibrous and porous or almost as compact as clay, and, hence, may vary greatly in weight and density. Johnson¹ quotes a German classification of peats, based on their physical properties, using the descriptive terms, "turfy," "fibrous," "earthy," and "pitchy"; the first including slightly decomposed materials, of light hue, soft, spongy, elastic, of very low specific gravity when dry, 0.11-0.26, a cubic foot weighing from 7 to 16 pounds; the second being more decomposed, the grass and wood fibers, etc., however, being still distinguishable, brown and black in hue, specific gravity 0.24-0.7, weight per cubic foot, 15 to 42 pounds; the third being destitute of fibrous structure, drying to earthy masses of lustreless fracture, its specific gravity 0.41 to 0.90, its weight per cubic foot 25 to 56 pounds; the last a dense, hard, lignite-like material of high specific gravity 0.62 to 1.03, and weighing 38 to 65 pounds to the cubic foot. Obviously there are peats and peats.

Color. Peat tends to darken on exposure, due doubtless to oxidation, to gaseous liberation, and to the consequent molecular simplification. A chocolate color is held by some to be an indication of the presence of ferrous salts, which are apt to act as plant poisons. It were well to stack and thoroughly weather a peat of this sort before using it on the soil.

Texture. This depends upon the sorts of growth from which and the conditions under which the peat was formed, and,

¹ Loc. cit., pp. 95-96 (1866).

as well, upon the completeness of disintegration. Peat made above the water level from tree and shrub growth, is woody in texture; that formed from grass-like plants or turf-forming plants near the water level, is fibrous and not apt to be greatly decomposed; a moss peat is usually devoid of fibrous structure; the mixed moss and sedge product of unweathered deposits shows considerable fibrous structure; while water plants form a soft structureless and oozy mass, often of high calorific value. Peats vary widely in texture even in the same bog from above downwards and from the center outwards to the circumference. The bogs are apt to contain several distinct layers from the surface downwards.

1. The yellow, green or red living mosses or other forms of plant life or their residues.

2. Their dead and dying roots, constituting a dark brown spongy, fibrous, coherent bed of greater or less thickness.

3. A blackish, partly decomposed stratum more highly decayed than that above it, yet tenacious enough to form turf, if the material is of moss origin.

4. A black layer consisting mostly of decomposed moss, or other plant structure, including more or less decayed stumps, roots, and tree and shrub residues.

That a bog should vary in the character of its product as it is formed from the center to the periphery of a basin, is evident when one notes the variation in the character of the vegetation which predominates in the several parts of the bog and considers the inevitable shallowing of the basin.

Absorption. Peat possesses great absorptive powers. It will absorb and hold immense amounts of water. These are held mechanically in part and in part are held within the cell walls and cavities. Pressure will remove some but not much water and the rest must be removed, if at all, by drying. Different peats hold different amounts, the more thoroughly disintegrated sorts carrying less than the more fibrous sorts. The former dry out the more readily to a hard texture, while the latter when

dried rapidly absorb moisture again and attain an air dry condition which is highly variable. According to the weather conditions an air dry peat may carry anywhere from 15 to 40 per cent moisture.

Weight and density. Peats vary greatly in this respect. The actual specific gravity of peat is greater than that of water, but, owing to its porous nature and to the inclusion of multitudinous air spaces, its apparent specific gravity is much less. Thus some very fibrous and slightly decomposed mosses show an apparent specific gravity of barely 0.1, while the compact, fine textured, highly decomposed and dry sorts may exceed 1.0. A large admixture of mineral matter tends to increase the weight. Obviously all these matters have bearing on transportation costs and storage charges as well as on fuel values.

The physical characteristics of a peat are important, being often the determining factors as to the possibility of its availability for a given purpose. Davis¹ says touching the relation of the physical condition of the peat to its exploitation that "the availability of a given peat deposit for certain definite prospective uses depends much upon the physical condition of the plant remains contained in the peat. Thus, if the peat is to be used for making paper or stable litter there should preferably be a large amount of well-preserved, fibrous matter available, whereas fine-grained, structureless, compact peat, so desirable for fuel, must be rejected. If the peat contains layers of well-preserved woody plant structures, especially roots and logs, the cost of preparing the bog for working is increased and its actual exploitation is rendered costly and slow unless powerful machinery be used. Peat containing much tough, fibrous matter is often difficult to grind in the usual type of peat machine because the knives become clogged by the fibers. Poorly disintegrated grassy and mossy peat is not suitable for most types of briquetting machines, because the briquettes made from it are

¹ Loc cit., pp. 44-45.

very light in weight and particularly likely to break up into thin plates when handled or when in the fire. Therefore, it is very desirable and even essential to learn as much as possible of the physical properties that are necessary to insure success in some chosen field of exploitation. A quality of peat which is adapted to the use should then be sought."

FUEL USES OF PEAT

Peat has been used as a fuel for centuries. Roman writers cite its use two thousand years ago, it has been Ireland's main supply for many centuries, and the poorer folk of North Europe in general have always largely used it and still continue so to do. It is employed on the Continent both for domestic and for power purposes. Every European country in the peat belt is yearly increasing its output of peat fuel. New processes for its utilization are being developed and there are several experiment stations in northern Europe whose sole reason for existence is peat study. Canada, "Our Lady of the Snows," burns much fuel. Her available coal supplies are not plenty, but her peat beds are extensive and well distributed. Hence in certain sections of Ontario and Quebec much attention has been paid to peat fuel production. Some of this has been used in gas producers and gas engines to good advantage¹, but no great commercial successes have been recorded.

Prior to the general use of coal, peat fuel usage was not uncommon in New England, the deposits being locally consumed. Some interest was evinced in a commercial way in the sixties but no success was attained, and nothing more was done for the forty years prior to the coal strike of ten years ago. Since that time, however, much effort has been expended and large sums employed in the attempt to commercialize peat fuel. Some of these enterprises are still under way and, benefiting by the errors of their predecessors, seem more likely to succeed. But when all is

¹ Can. Dept. Mines, Mines Branch, Bul. 4 (1910).

said it cannot be gainsaid that there is less need of peat fuel in this land of anthracite and bituminous coals, of natural gas and petroleum, than in countries less well blessed. Yet the peat beds of this country are great latent resources of fuel which are lying unused, which are not harming by non-use, and which some day may be of service.

Peat makes a good fuel, not an ideal but a good one. Fuel usage differentiates sharply between peat and muck. It is not too broad a distinction to say that a deposit which can be used for fuel purposes is a peat, while one that thus cannot be used is a muck. Yet not every peat makes good fuel. Certain conditions are inimical to fuel uses. Thus the ash content must be relatively small, the allowable maximum being variously set from 10 to 25 percent. Vermont peats seem commonly to carry less than this and many samples reported in this survey carry less than 5 percent ash. The injurious effect of a high ash content is readily seen when one realizes that it is not only valueless as a fuel, but that the heat used to raise it to and to maintain it at the temperature of the fire, is unprofitably employed. Furthermore, the costs of excavation and transportation are relatively increased by the presence of excessive ash percentages. Fortunately peat ash is light and feathery and does not form clinkers. (See Plate IX.).

The water content of a peat has bearing on its fuel value. It may carry 90 percent when dug and when air dried usually contains fully 25 percent water, which replaces an equivalent weight of combustible matter. Not only are production costs increased by its presence but large amounts of heat are wasted, as far as economic uses are concerned, in its vaporization. Dried peats, moreover, absorb water readily from air, so that this is always a factor, and a variable one at that, to be reckoned with.

The deleterious effect of the water and ash contents on the heating powers of peat is well shown in the following table.¹

Dry peat, ash free	6500 calories
Dry peat, 4% ash	6300 calories
Dry peat, 12% ash	5800 calories
Dry peat, 15% ash	5500 calories
Dry peat, 30% ash	4500 calories
Dry peat, 25% water	4700 calories
Dry peat, 30% water	4100 calories
Dry peat, 50% water	2700 calories
Dry peat, 30% water, 10% ash.....	3700 calories

The totality of heat units does not always measure the relative values of fuels. Thus in metallurgical processes, for instance, the quantity of heat is less important than is its intensity. A fuel which affords the most heat does not always produce the greatest heat. The one depends upon quantity, the other upon quality. To determine the intensity of the heat produced, one needs to know the available quantity produced by the combustion of a given weight of the fuel, the weight of the combustion products, and the number of heat units required to raise 1° F. the combustion products formed from this given weight of fuel.

THE PRODUCTION OF PEAT FUEL

Davis' monograph discusses the preparation and manufacture of peat fuel at length. He cites the many failures in peat deposit exploitation due to ignorance, inexperience and to faulty engineering. He states that the market for the fuel, the transportation facilities, the location and size of the bog, and the quality as well as the quantity of its contents, are important points. He cites approved methods of determining these points, including chemical and mechanical tests, surveys, etc. He indicates how the bog may be prepared and drained, the plant-site chosen, its layout determined both as regards buildings and machinery; and, finally, the matter of capitalization is reviewed. He then discusses the methods of producing "cut peat," "machine peat" (wet process peat), "peat powder" and "peat briquettes,"

¹ Handbuch der Torfgewinnung, p. 333 (1904).

wet carbonization, peat charcoal, peat coke and the sundry tar by-products, as well as illuminating and producer gases.

It does not seem necessary or desirable to discuss these various matters at length, save in one respect. It is so entirely feasible to make local use of many Vermont peat deposits as fuel by the "cut peat" process, that it seems worth while to let a Vermonter tell his story of how he has done it to good advantage for years, how he has done in Vermont what generations have done in Europe and particularly in Ireland. The operation is a simple one, the equipment inexpensive and easily handled and small deposits may be thus easily and cheaply worked. It would seem as if this process might be worth using in the production of fuel for local use.

John Webster of Franklin, Vermont, who is a veteran maker of peat fuel and whose deposit is described on pages 186-7 writes as follows under date of Jan. 5, 1910.

"When building and draining a road across a 100 acre beaver meadow bog in Franklin it was found necessary to cut wide ditches upon each side. The formation was shaky and saturated with water; yet we had no trouble in opening the ditches 9 feet wide and 2 feet or more deep. After taking off 6 inches of sod (the meadow was covered with wild grasses), it was found that the underlying material could be removed in firm and readily handled chunks, which, when dried, burned well. Even when only partly dried they made a steady hot fire, kindling easily and leaving from 5 to 7 percent of light ashes. The next year and for the nine succeeding years I cut and dried from 5 to 10 cords annually, using it in the cookstove and open grate with good success. I estimate that the bog would cut 2,000 cords per acre when cut six feet deep. Of course at first I had to learn how to use it, and what kind of a stove was best suited to make an economical fire.

This bog was partly in grass and partly bushes. The owner was desirous of improving it for the better growth of wild hay.

It was decided to cut ditches 12 rods apart from the edge to the stream which flowed through the center of the marsh. These ditches were 12 feet wide at the top taking off the sod about 6 inches deep. The tools used were a sharp spade, bog hoe, an ax, shovel, and a peat spade made expressly for cutting peat. (Plate I). We used two of the last named tools as we threw out the blocks on each side, cutting from the side to the center each way.

*How to take out the peat.*¹ First stake out the center of the ditch, then mow all grass and brush from the center line for at least 3 rods each way in order to make a drying ground. Spread the hay and small brush evenly thereon, and then stake and line out the sides of the ditch. After removing the sod, commence at one end and cut square across with the common spade about 1 foot deep. Then, taking the peat spade which is 4 inches wide with a lug or lip on one side of the same width and 16 inches long, (Plate I) begin at one side and cut out the first row of blocks. These will be triangular in shape, the next row will be square but not quite of full length, and the third line, as well as the remainder, will be about 4.5 inches square by 16 inches long. Let a man on each side of the center proceed in this manner working backwards until one spade deep has been thrown up. The same operation is repeated until the peat is dug as deep as is desired or as deep as it extends. We usually cut out three layers, but have thrown out four or five. If there is help enough, have a man with a wheelbarrow on each side to remove blocks to the drying ground where they can lay evenly on the ground side by side, commencing at the back or further side of the drying ground and working towards the ditch. An occasional root or stump may be met which usually the spade will cut through. The water has never prevented us from finishing a day's cut, but it comes in during the night partly filling the ditch; hence one should leave a partition be-

¹ The bog will often handle better if drained the year previous in the section where digging is to be done.

tween the different days' cuttings of, say, 15 inches to keep back the water.

How to dry peat. The wet blocks, carrying 50 to 90 percent water, dry out as they lie loosely on the cut hay and brush. A week's exposure to sun and wind vaporizes about one-half the water.¹ The blocks should then be turned over. A pitchfork was found to be the best tool for the purpose. After another week or ten days of fine weather, the blocks should be "cobbled up," i. e., built-up cob-house fashion to the height of 2 to 2½ feet, (Figures 1 and 2) to remain until dry enough



FIGURE 1.

to put in the shed, (Plate II) which, in fine weather, will be about one week. If the weather should be stormy or if no shed is convenient, the peat should be stacked.

How to build the stack. Only after several trials did I learn how. Lay down a bottom of rails and old boards so as to allow air circulation and to favor drying. Begin the stack five or six feet wide and as long as needed. Lay a tier of blocks on the bottom across, and another on that the other way, keeping the blocks about an inch or less apart—never touching—so as to let the air pass through and vaporize the water. After 3 or

¹Artificial heat, unless a waste product, is uneconomical inasmuch as more heat units are required to dry the peat than it itself will yield. It is like paying out two dollars to gain one.

4 tiers are lain, leave, once in 4 feet, a hole through the stack at least 4 inches wide and two or three blocks high, the better to hasten the drying process. Build up in this way 3 feet and then draw in and top it off so that it will be about 6 feet high when finished. Twelve feet of such a stack will hold two cords. Peat stacks must be fenced if cattle run in the lots, as they will hook and rub them down. It is always best as soon as the fuel is in good condition to place it under cover where it will keep for any length of time. When dry enough to burn it will weigh about 30 pounds to the heaped bushel. A

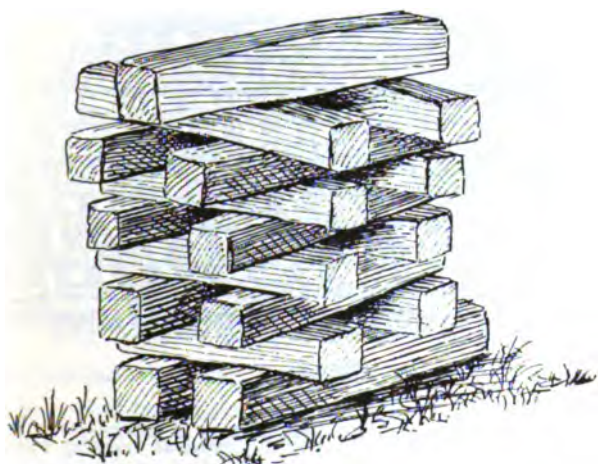


FIGURE 2.

cord will weigh about a gross ton and is equal to or better than good wood. I have used it together with wood in the sugar arch with good results. No ashes accumulate for the draft carried them all up the stack. If no gravel or clay adheres to the lower spadings no clinkers will form.

More or less breakage occurs in stacking the half dry and handling the air dry peat, but this is no disadvantage since as the pieces will be from 2 to 6 inches in length and handle better with the scoopshovel than the whole blocks. The fine broken peat can be used as an absorbent in the stable, a bushel basket full

being enough to dry the floor behind 20 cows. It should not be used as a bedding like straw or sawdust, but as an absorbent behind the cattle.

How to burn peat. Peat will burn readily in any stove. A few handfuls of broken pieces at the bottom in the wood kindling will start the fire at once. On account of the large quantity of ash as compared with wood, it is not convenient to use it in stoves made for burning wood, for after two or three hours the ash accumulations prove annoying. A cookstove fire kept constantly ablaze from morning till late in the evening formed 14

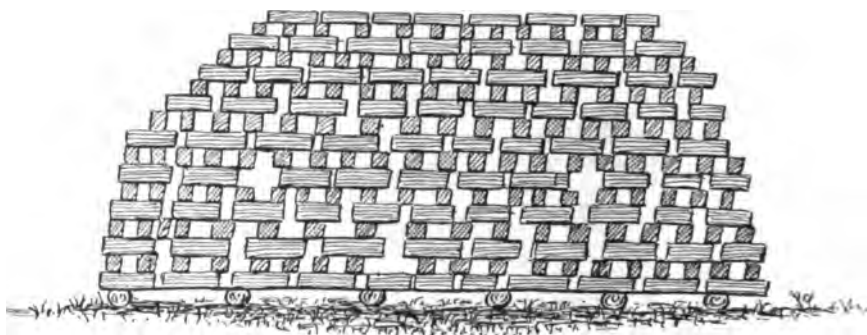


FIGURE 3.

quarts of ashes, hence a large ash pan is a necessity. A cord makes about 2 bushels of ashes, which prove valuable on grass land, garden or orchard. The fire box should be larger than is usual in wood stoves, and, after the fire has started, the draft should be nearly closed. Peat makes much flame, hence the fire box should not be more than two-thirds filled lest it choke and prevent free combustion. (See Plate IX.).

What does it cost to prepare peat ready for use for fuel purposes? In such a ditch as I have described two men can easily throw out in an eight-hour day, after the sod is removed, 18 to 20 feet in length, about 8 solid cords. Some shrinkage occurs in drying, hence it might not be safe to figure on more than 7 dry cords. At \$2 per day the excavation would cost 57 cents per

cord. As much more should be added for drying and stacking or housing, a total of \$1.14 per cord. I consider this a safe estimate. I have repeatedly done much better in good weather. I deem it worth as a fuel from \$4.50 to \$5.00 a cord. Seventy-five heaped bushels make one cord, which weighs a gross ton. I sold my surplus at 6 cents per bushel, or \$4.50 per cord, which leaves a good margin for profit.

When to cut peat. In northern Vermont at any time after mid-May. Frost injures it badly when it is first taken out, so that it is best to wait until all frost dangers are past. It may be cut at any time during the summer, even as late as September first, with a good prospect of securing it before winter. My experience indicates that freezing does it no harm when it is dry enough to stack, and that the blocks dry out in a few weeks.

The time will come when Vermont's peat deposits will be used more than at present. They are numerous and extensive, but are not generally considered to be of great value, because the people hardly know what peat is, or what use can be made of it."

THE PRESENT STATUS OF PEAT FUEL USAGE

Multitudinous schemes for the effective commercial utilization of peat as a fuel have been tried but, generally speaking, most of them have proved failures in this country, though some of them have been successful in Europe. It has not been able thus far in this country to compete with anthracite and bituminous coals, with natural gas or petroleum. The main difficulties which have hitherto stood in the way of its economic fuel use have been its comparative dilution, its excessive bulk, and the high cost of drying, briquetting and transporting.

Peat is now attracting much notice as a medium for the production of various gases. The terms "blast furnace," "producer" or "generator" gas are applied to the waste gases which emerge from the top of a blast furnace, or are obtained by the partial burning of fuel subjected to a strong air current in a

special furnace termed a gas producer or generator. The operation is so conducted that a very thick fuel layer is incompletely burned, the gases being withdrawn and stored in combustible form. They consist mainly of carbon monoxid and nitrogen. Blast furnaces usually carry roughly one-third or two-thirds, respectively, of these two gases, while producer gas is apt to carry about one-fourth carbon monoxid, three-fifths nitrogen, one-eighth hydrogen, with traces of carbon dioxid and methan.

Davis¹ says, touching the availability of peat for this purpose, that "the present state of knowledge seems strongly to indicate that large peat deposits can be most profitably utilized, and the largest percentage of the stored-up energy in them recovered as power, by converting the peat into producer gas and using this gas in properly designed gas engines. The power may be used by factories operated on the spot, or, as electric energy, may be used at a distance. Large plants, by using by-product gas producers and thus at least recovering as ammonium sulphate the ammonia that is formed during the destructive distillation of the peat, may be able from sales of the sulphate to pay a part of the expenses of the whole operation. The by-products process, however, may not be feasible for gas-producer plants of small size, because the costs of installation, maintenance, and supervision are proportionately higher for small than for large plants, and the quantity of by-products obtainable from a small gas producer is not sufficient to keep a recovery plant in operation continuously.

Even without any by-products the use of producer gas presents so many advantages that wherever peat beds are to be used as sources of fuel for power installations of more than 100 horsepower, the possibilities of a producer-gas plant should be given serious consideration.

The producer-gas plant may also be readily adapted to metallurgical work, to firing kilns for brick, porcelain, lime, and probably for cement manufacturing. It might have a large use

¹ Loc cit., p. 162.

in roasting ores and, in a smaller way, in foundries and other iron-working plants, and in reheating and refining steel, copper and other metals when fuel free from sulphur is required.

Even for boiler plants that could use peat fuel, a gas producer would be a most desirable adjunct, as it would permit the use of peat less carefully prepared and containing more water, and the economy would be greater than in any other way of firing."

Davis¹ summarizes a hundred pages of discussion of the use of peat for fuel as follows:

"The facts presented (as to the fuel value of peat as compared with that of coal and wood for firing boilers, furnaces and stoves) demonstrate that although plainly inferior to the best coal in the number of heat units yielded per pound consumed, nevertheless, if prepared in the ways commonly used in Europe, peat fuel presents so many desirable qualities, such as freedom from smoke, cleanliness in handling, small ash content, complete and easily controlled combustion, and prospective low price, that there should be a good field for its introduction for manufacturing and domestic uses in those parts of the United States where peat naturally occurs in abundance.

Utilization of deposits. There are many bogs in the peat-bearing regions which, although too small to warrant establishment of large plants, could be utilized to furnish machine peat enough for boiler fuel for a single small factory for many years. They might also furnish the power to pump water and generate electricity for a small community for an equal length of time.

The principal matter to be borne in mind in preparing to exploit a peat deposit in such a way is that the simplest equipment which has proved it can yield the desired quantity of usable or salable fuel is the one most likely to give satisfactory returns either in fuel or money. Every added process of treatment beyond that which is necessary to put the peat into usable form for a specific purpose, adds many times to the first cost of equip-

¹ Loc cit., pp. 161-163.

ment and to the practical difficulties of making a product that can be sold for enough to pay the costs of preparation and of putting it on the market at a profit.

Next to producer gas,¹ *peat powder* is the most attractive form of fuel for firing boiler furnaces, for operating kilns of various sorts, and for the metallurgical operations mentioned. This form of peat has not yet been so generally used in Europe as has producer gas, and not as much has been demonstrated commercially in regard to its value. The most recent reports are very favorable and indicate that peat powder can be cheaply produced and is as good fuel for boiler firing when properly prepared and fired as the same weight of good English coal.

Domestic uses. The steadiest and, in the aggregate, the greatest demand for peat fuel may be expected to come from small consumers, who want a clean, easily handled, and cheap fuel that gives out a steady heat and yet responds quickly to changes of draft when burned in ordinary heating and cooking stoves. Doubtless in this way, as a supplementary and auxiliary fuel, much of the peat that is gathered for fuel will be used.

Peat coke is the most efficient solid fuel derived from peat, but its high cost of preparation will doubtless limit its use even more than that of charcoal is now limited. Its value for all uses to which charcoal is now put should find it a ready and satisfactory market after it has once become known to the industries that require such a product."

Before an intelligent report can be made a peat prospector needs information concerning many points such as the extent and accessibility of the bog, the quality of the material, drainage facilities, price and availability of labor, climatic environment as regards humidity, sunshine, frosts, etc., and the likelihood of a reliable market. A large working capital and intelligent supervision are also essential. Quality tests should cover ash and carbon percentages and calorific values and should be made on thoroughly representative samples. The fuel content of a deposit

¹ For statement by Davis touching producer gas see p. 164.

may be roughly estimated by multiplying the product of the acre area and the average depth in feet, by 200, which is the number of tons of air dried peat ordinarily obtained from an acre one foot deep.

Davis says touching relative values in his peat fuel monograph¹ hitherto liberally quoted from, that "peat fuel may be said to be especially useful for certain purposes for which wood was formerly in general use and for which coal has not yet been altogether successfully introduced, such as brick and other forms of ceramic firing and lime burning. It appears to reach its highest value, however, as a source of producer gas in properly constructed gas producers. This is a very efficient way in which to use its energy.

The fact must be noted that no quantity of peat fuel of any type sufficient to prove its value has yet been produced in the United States; until this has been done, although the outlook and European experience warrant further investigation of its possible uses and value, no final conclusions as to the commercial value of American peat as compared with coal can be reached."

What are the comparative merits of peat and coal as fuel? The former is relatively bulky and transportation and storage charges militate against its use. Its calorific value even when compactly pressed is less than that of anthracite. At present there seems little likelihood that at any material distance from the production plant can peat fuel compete with wood or with anthracite. That processes may be devised, however, which will make it a serious competitor is not unlikely.

A series of Ontario analyses¹ compares peat, lignite, bituminous and anthracite coals as follows:

	Carbon	Hydrogen	Oxygen	Nitrogen	Sulphur	Ash
Peat,	54.	5.2	28.2	2.3	0.6	9.7
Lignite,	66.3	5.6	22.8	0.6	2.4	2.3
Bituminous coal,	78.7	6.	10.	2.4	1.5	1.4
Anthracite coal,	90.4	3.3	3.	0.8	0.9	1.6

¹ Loc cit., p. 15.

NON-AGRICULTURAL USES OF PEAT, OTHER THAN FOR FUEL

There seems no need in this bulletin to enter at length into this phase of the matter, for there appears but little likelihood that any Vermont deposit will be used for purposes other than the production of either fuel or fertilizer. Suffice it, therefore, to say that many things are made from peat in Europe, including such chemicals as acetic acid and acetates, wood and ordinary alcohol, formaldehyde, ammonia and its salts, creosote and such derivatives from the peat tars as illuminating and other oils, paraffin wax and asphaltum. Ammonium sulphate, an important source of nitrogen in commercial fertilizer manufacture, is being made in a commercial way from peat; and there seems some reason to believe that in the not distant future nitrates may be thus made. Brown dye stuffs; tannic acid, tannins and related substances serviceable in tanneries; box card board and low grade paper stock; coarse cloth (horse blanket cloth); and a sort of artificial wood are made. The more fibrous or mossy forms are used in making mattresses, particularly serviceable for hospital use on account of their light weight, softness, lack of odor, and low cost; for packing fragile and perishable articles (fish, eggs, meat and fruit); and for florists' use. And, finally, peat powder has been used as a crude antiseptic in dressing wounds, cuts, burns, etc., as well as a deodorizer and absorbent in the disposal of household wastes, in earth closets, etc.

AGRICULTURAL USES OF PEAT

The farmer directly or indirectly can make much use of peat, and use is being made of it for him, perhaps not always to his benefit. It is employed in several ways.

1. As a fertilizer and soil amendment in the vicinity of its excavation, either alone or composted.
2. As an absorbent in the stable.
3. As a litter in the stable (if fibrous).

¹ Carter, Ont. Bu. Mines Rpt. 12, p. 194 (1903).



PLATE I.—A view in a Franklin, Franklin county, peat bog, showing peat slane or spade and several slabs of peat as excavated. (See pages 158-163, 186-187, 226).



PLATE II.—A drying shed used in Franklin, Franklin county, for drying peat for use as fuel. Note the piled peat as seen through the entrance. (See in this connection the description of process and figures on pages 158-163).



PLATE III.—A view of the Heminway swamp in Bridport, Addison county. (See pages 179, 204-205, 223).



PLATE IV.—Bristol Pond near Bristol, Addison county. (See pages 180, 204-205, 223).

4. As an insulator.
5. As a stock food.
6. As a preservative.
7. As a fertilizer filler.
8. When burned to ashes, as a fertilizer.

1. *As a fertilizer and soil amendment* in some sections peat or muck is drawn directly from the bog and spread as a top dressing. Good results usually are attained though they may not be at once apparent. The benefit, however, seems to be a lasting one. Theoretically this is not an ideal practice. Peat nitrogen is but slowly available. Other methods which more quickly render this element available are to be preferred as a preface to soil application. Furthermore, the organic acids commonly formed as a result of fermentation tend to inhibit or unfavorably to alter crop growth. However this very acidity serves some good purposes. The basic elements of plant food, such as calcium, potassium, magnesium and others, normally exist in insoluble silicate combinations which the organic acids thus developed tend to dissolve, forming relatively soluble and available humates.

Piling peat on dry ground for a year or more before using it is a practicable way of utilizing it. Its nitrogen becomes more available, its organic matter decomposes. When air dried it may be used in several ways.

- a. It may be applied directly to the soil.
- b. It may be used in the stable, not as a bedding but preferably as an absorbent of the urine, being placed in the gutter.
- c. It may form the basis of a compost heap, being built in alternate layers with other materials (manure, farm wastes) to a height of three or four feet or more and of indefinite area. Where thus constructed it should be kept moistened with urine or other liquid, and should otherwise remain undisturbed for several weeks, when it may be stirred thoroughly and left for further decomposition and drying out. A peat or muck and barn yard manure compost is very well worth while. The bacteria

in the manure tend to ferment the peat; the peat contains ingredients which tend to inhibit a too rapid manurial fermentation. Such a compost is a practical and economical method of extending the manurial resources of the farm and is highly recommended. Lime, sometimes conveniently obtained from the marl beds which often underlie the peat deposit, is a serviceable ingredient in such composts, provided it does not contain manure. Composts containing manure are injured by lime.

In reclaiming peat soils the land must be cleared, if wooded, the area ditched and, if possible, cross ditched. Wild peat lands are generally unproductive, grass being their main herbage, but when thoroughly drained and correctly managed they can be made to produce large crops of corn, grass, celery, tobacco, cabbage, onions, etc. They are apt to be relatively lacking in the several mineral forms of plant food. Potash salts are usually found very effective, sometimes phosphoric acid is a help, as well as lime; the plowing under of coarse manure or straw is highly recommended. Doubtless the former procedure furnishes a deficient element while the latter induces a rapid decomposition of the peat deposit because of the introduction of the bacteria normally present in the manure.

The organic matter of peat serves to better the mechanical condition and hygroscopic properties of sandy loams and to furnish humus to soils denuded thereof. Soils thus amended absorb and hold water more readily; their temperatures are augmented by the decomposition thus induced, as well as by their darkened color, but are lowered by the increased water contents which result from peat usage.

It is well known that clay soils in drying out, shrink, crack, and tear plant roots. Peat applications in sufficient quantities tend to some extent to overcome this evil. The mechanical improvement is not wrought at once but in a year or two. After disintegration and weathering have taken place, the desired result is apt to be attained and crop production enhanced.

Only peats low in ash contents should be used on sandy soils; those high therein are better adapted to clay loams where humus is less likely to be lacking. Complaint is sometimes heard that when applied to light soils peat wears out too quickly to be of advantage. This is usually due either to scanty applications or to its infrequent use. When freely used on sandy or gravelly soils it often works admirably. It should do excellent service if applied two inches deep over the land with a manure spreader, with freshly slaked lime used at the rate of 5 or 6 bushels to the cord of peat, the whole thoroughly harrowed into the soil and then subsequently plowed to a depth of 5 or 6 inches.

Peat soils are usually acid. Neutrality or slight alkalinity is usually desirable. The litmus paper test or the growth of the tell-tale row of beets will determine the facts.¹ A heavy dressing of lime, preferably as quick or slaked lime, or a very heavy dressing of carbonate should prove effective.

2. *As an absorbent.* Peat is admirable in this respect, absorbing eight times its weight of urine, more than twice what straw will hold. Not only is mechanical waste lessened but fermentation to some extent is inhibited by its deterrent action. It also tends to absorb and to fix ammoniacal gases. It is in every way to be commended for use in the trenches behind the animals; but as a litter or bedding it is less desirable, unless of a fibrous nature, on account of its dustiness. It works well in barn yards or in earth closets.

3. *As a litter or bedding in the stable.* If dry, and particularly if fibrous, it makes an admirable litter from the standpoint of the animal, furnishing a good surface both for standing and lying down, springy, absorbent, dry and not too hard; but it is apt to be too dusty for satisfactory use in dairy barns. Its effect on the feet, indeed on the general well being of the animals, is excellent. It is unfortunate that its one bad property, dustiness, is so apt to outweigh so many good ones.

¹ See Vt. Sta. Bul. 160, p. 422 (1911).

4. *As an insulator.* Being a non-conductor of heat when dry and fibrous, it is well worth using as a packing for water pipes as against freezing, and in ice houses, storage houses and the like.

5. *As a stock food.* Dried ground peat has of late been employed in Europe—and is being offered in this country—as an absorbent for molasses, the product being used as a cattle food. An analysis of a German 4 to 1 mixture published some years ago, showed roughly 25% water, 40% sugar, 10% each of ash and protein, and 15% carbohydrates other than sugar. The service of peat as an absorbent is beyond question; as much cannot be said as to its food value. One can hardly believe that such a material would be likely to contain any considerable amount of digestible nutrients. If one wishes to feed molasses to his stock, let him do so using home grown absorbents (cut hay, straw), or putting it on silage. It is not known that the peat does any harm; indeed testimonials—not the result of careful feeding trials—are not wanting as to the beneficial results attained in feeding heavy rations of molasses thus absorbed. If one has plenty of peat on the farm and no other absorbent is available it may be worth using; but the writer doubts it.

6. *As a preservative.* Air dried peat, being slightly antiseptic in its qualities as well as a non-conductor, serves an excellent purpose as a material in which to pack eggs, fruit, vegetables and the like for storage, whether within or without a refrigerator. It tends to lessen shrinkage by evaporation. It does not prevent but tends to lessen decay, and to prevent its spread by contact. Fish, a notably putrescent material, when packed in peat, keeps untainted for many days. As evidence of this preservative effect may be cited the finding, less than a century ago, of two well preserved human bodies in a European moor which from their dress and ornaments had clearly lain there for nigh twenty centuries.

7. *As a fertilizer filler.* Peat is being used in largely increasing amounts as a fertilizer filler. A "filler" is a material

used for makeweight purposes, that is to say as a diluent, or to improve mechanical condition. Manufacturers prefer to use the more euphuistic term, "conditioner," or "dryer." Its function in this respect is to prevent caking or the formation of lumps, to dry the goods, to lessen the time necessarily elapsing between manufacture and sale, to improve drilling qualities. All these good offices are admirably accomplished by peat, which is prepared for the purpose by the simple procedure of plowing and draining till air dry, drying, usually in a rotary dryer to a low moisture content, and powdering.

Peat when thus used does more than better the mechanical character of a fertilizer; it likewise increases its total nitrogen content. The nitrogen thus added has undoubted fertilizing value; but it does not rank with the more readily available forms commonly purveyed in the fertilizer trade, being relatively inert, unless put through a "wet mix" process, by which it is in part, but by no means fully, made available. It is not just to rate it on a par with the more available forms, to include it in the mixing formula or in the guaranty statement. Manufacturers who, say, guarantee 2.5 percent nitrogen should furnish fully that amount from such forms as are recognized to be relatively available, and should not count the peat nitrogen as a part of their formula or guaranty. This is especially necessary when goods are "dry mixed" with peat. That peat is very serviceable as a conditioner of goods largely made up of mineral constituents is granted. Its use is more frequent to-day than formerly, in part because of the fact that approved forms of organic nitrogen are costly and more difficult to obtain than in previous days and in part because on this account more mineral nitrogenous stock is used, which tends to cause caking and injuriously to affect the drilling properties of the goods. But that this situation warrants a manufacturer in claiming for, or a fertilizer control in granting to, peat nitrogen a rating as high as that of nitrogen derived from tankage, is at least a moot question.¹

¹ In this connection, see Vt. Sta. Bul. 160, pp. 319-327 (1911), touching the availability of organic nitrogen in commercial fertilizers.

Peat has been used to some extent as a dryer in the manufacture of calcium cyanamid, a material which is entering the fertilizer trade in large quantities. Its use for this purpose is now discontinued.

8. *As ashes.* Cleared peat bogs are sometimes burned over with a view of bettering their condition. The practice is of doubtful advisability. Peat ashes do not begin to measure up to wood ashes in value. The mineral constituents are thus made more concentrated and the acidity of the material entirely neutralized; but organic matter is wasted, fuel value sacrificed, nitrogen lost. The burning of peat bogs is an exceptionally advisable but rarely desirable procedure. The ashes which are gained are slight compensation for the humus and the nitrogen which are lost.

The nitrogen content of a peat may be considerable and is always a quantity to be reckoned with; but its phosphoric acid and potash contents are negligible, and its lime content not large. The ash may carry roughly 1 percent potash, 2.5 percent phosphoric acid and 25 percent lime. An air dried peat carrying a 10 percent ash content would, therefore, contain in a ton about 20 cents' worth of phosphoric acid and potash and perhaps 15 cents' worth of lime, rating these ingredients at the same prices at which they would naturally be purchased in the markets as quicklime or in commercial fertilizers, a rating which, of course, is relatively too high. Clearly peat ashes are not worth much and, furthermore, their light, fluffy character is such that their economic use is almost out of the question.

HOW MAY ONE TELL WHETHER A BOG IS OR IS NOT WORTH WORKING EITHER FOR FUEL OR FERTILIZER?

One ought to know both the extent of the deposit in area and in depth and its general quality. If one contemplates only personal use and the deposit is clearly of considerable area, the latter item alone needs consideration; but it should be understood that unless thoroughly representative samples are secured

the results attained may be quite erroneous, and that the quality of a peat or muck may vary in different parts of the bog either laterally or perpendicularly. One sample taken near the edge, and another near the middle may vary greatly in character, on account of differences in the nature of the original vegetation. Then, again, the surface peat which is relatively fresh and either living or not long dead, is likely to be of a very different character from that which lies far down in the depths and which has lain there for ages. Samples should be taken carefully at several places and at several depths in order thoroughly to represent the deposits. These should either be mixed and a composite sample formed therefrom or, if there are clearly several different types showing varying characteristics, they should be kept separate. It were well to lay out definite lines across the bog at definite distances on which at definite points test holes should be dug in order to show the character and depth of the various layers and for purposes of sample taking. There are several sorts of sampling augers adapted to this purpose; but the local owner, who will be likely to sample, if at all, once in a lifetime, may do so with a spade. He should be over-careful, over-conscientious in taking many samples rather than the reverse, and should make a record of the locations of sample taking.

The only true test of the quality of a peat or muck is that of analysis. The Vermont station has analyzed many samples from all parts of the State (see pages 204-240) and stands ready to test more. Analyses of Vermont samples, unless forwarded in unreasonable numbers, are made without charge. Parties sending samples should specify whether fuel or fertilizer usage is contemplated. If no statement is made, analysis for fertilizer usage will be reported.

It seems safe to predict that the future development of the peat industry will be likely to be along lines of producer gas making, the discovery of successful means of drying and briquetting, the manufacture of peat charcoal and coke, of paper

and pasteboard, of a deodorizing stable litter, of fertilizer filler, and the utilization of peat deposits as agricultural lands.

IV. CONCERNING THE VERMONT SURVEY

This study of the peat and muck deposits of Vermont is simply a laboratory study. It would have been desirable, had opportunity permitted, to have supplemented it with field trials, involving the excavation and reclamation of peat lands and the application of the excavated product on sundry soils to supply them with the humus needed to meet soil deficiencies. However, such trials lie rather within the province of the individual owner of the peat or muck, whose attention is called more particularly to the matter shown under head III, pages 155-175, relating to methods of reclamation and usage.

In order to secure definite knowledge of the existence and location of the deposits, inquiries were sent to the town clerks in the several towns. To roughly three-fourths of the letters courteous replies were received; to a fourth part no answer was made. From information thus received and otherwise obtained, there seems reason to believe that peat and muck deposits of considerable size exist in at least two out of three towns throughout the state.

The State Geologist, Prof. G. H. Perkins, whose wide acquaintance with Vermont and special information on this subject entitles him to express his views, intimates that in his opinion almost every town, and, indeed, almost every Vermont farm, possesses a peat or muck bed of greater or less extent, the very existence of which in many, perhaps most, cases is unknown. No opportunity offered for a full survey of the State as to its peat resources, but during three successive seasons one of the writers (F. M. H.) covered the State, superficially to be sure but sufficiently to attain a general knowledge as to the extent of the deposits in many sections. He personally visited and examined the deposits represented by the samples reported on pages 178 to 233. Obviously he did not survey every bog in Vermont.

Several which he knew about he was unable to visit; concerning the existence of many others he was ignorant. The survey then is simply a partial one, but it is felt to be sufficiently representative to be of service.

The statements appearing on pages 178 to 204 epitomize the correspondence of 1905 and the notes taken in three surveys made in 1904, 1905 and 1907. Every definite statement by the town clerks is noted; the essential characteristics of each deposit visited are described; and such details touching sampling operations as serve to explain the character of the samples drawn are afforded.

The order of statement by counties is: town, sample number¹, name of owner (or tenant) of farm at the time of sampling, approximate area, physical characteristics of the deposit, etc.

Two hundred and forty-four samples were collected, 82 in the fall of 1904, 62 in the fall of 1905 and 100 in the summer and fall of 1907. They were drawn in 42 towns representing 12 of the 14 counties. The most extensive and valuable bogs were found to be located in Addison, Franklin, Grand Isle, Chittenden, Windham and Orleans counties. Complete analyses were not made of all the samples collected. Quite a number of known high ash content were omitted altogether, thus reducing the number of samples upon which ultimate analyses were made to 183. The partial analyses of 23 of the 27 discards of 1904 are displayed on pages 236-237 in connection with the samples sent on for examination.

The town clerks' statements made in 1904 to 1907 as to the location of deposits are epitomized in the following statements: The mark (x) indicates doubt on the part of the party making the report as to the actual existence of deposits; the mark (*) indicates the belief of the writer that probably deposits exist, the

¹ Samples 1-82 were drawn in 1904, samples 101-162 were drawn in 1905, samples 201-300 were drawn in 1907.

negative report of the town clerk—or non-report—to the contrary notwithstanding.¹

ADDISON. *Deposits*—Bridport, Bristol, Cornwall, Ferrisburgh, Lincoln (x), Monkton, New Haven, Orwell, Salisbury, Shoreham, Starksboro, Vergennes, Waltham, Weybridge, Whiting, 15. *None known to town clerk*—Hancock, Middlebury*, Pantown*, Ripton, 4. *No reports*—Addison*, Goshen, Granville, Leicester*, 4.

BENNINGTON. *Deposits*—Bennington, Dorset, Manchester, Pownal, Searsburg, Shaftsbury, Sunderland, 7. *None known to town clerk*—Glastenbury, Landgrove, Rupert*, Stamford, Winhall, 5. *No report*—Arlington, Peru, Readsboro, Sandgate, Woodford, 5.

CALEDONIA. *Deposits*—Barnet, Burke (x), Danville, Hardwick (x), Kirby (x), Ryegate, Stannard (x), Sutton (x), Walden (x), Waterford, 10. *None known to town clerk*—Groton*, Newark*, 2. *No reports*—Lyndon*, Peacham, Sheffield, St. Johnsbury, Wheelock, 5.

CHITTENDEN. *Deposits*—Bolton, Charlotte, Colchester, Essex, Hinesburg, Jericho, Milton (x), South Burlington, St. George (x), Westford, Williston, 11. *None known to town clerk*—Shelburne*, Underhill, 2. *No reports*—Burlington, Huntington, Richmond*, 3.

ESSEX. *Deposits*—Brunswick, Canaan, Concord, Granby, Guildhall (x), Lemington, Lunenburg, Maidstone, 8. *None known to town clerk*—Brighton*, East Haven, Victory, 3. *No reports*—Bloomfield*, Norton*, 2.

FRANKLIN. *Deposits*—Fairfax, Fletcher (x), Franklin, Highgate, Richford, Sheldon, Swanton, 7. *None known to town clerk*—Bakersfield, Berkshire, Enosburg, 3. *No reports*—Fairfield, Georgia*, Montgomery, St. Albans, St. Albans town*, 5.

GRAND ISLE. *Deposits*—Alburg, Grand Isle, Isle La Motte, North Hero, South Hero, 5.

LAMOILLE. *Deposits*—Cambridge, Elmore, Johnson, Morristown, Stowe, Waterville (?), Wolcott, 7. *None known to town clerk*—Belvidere, 1. *No reports*—Eden, Hyde Park, 2.

ORANGE. *Deposits*—Newbury, Randolph (x), Thetford, Tunbridge, Vershire, West Fairlee, Williamstown, 7. *None known to town clerk*—Bradford*, Braintree, Chelsea, Corinth, Fairlee*, Orange, Strafford, 7. *No reports*—Brookfield, Topsham, Washington, 3.

ORLEANS. *Deposits*—Albany, Charleston (x), Derby, Glover, Irasburgh (x), Morgan (x), 6. *None known to town clerk*—Coventry, Newport*, Westfield, 3. *No reports*—Barton*, Brownington, Craftsbury, Greensboro*, Holland, Jay, Lowell, Troy, Westmore, 9.

RUTLAND. *Deposits*—Benson, Castleton, Hubbardton, Ira, Mendon, Poultney, West Rutland, 7. *None known to town clerk*—Chittenden, Clarendon, Middletown Spa, Mount Tabor, Pawlet, Pittsfield, Pittsford*, Proctor, Sherburne, Shrewsbury, Sudbury, West Haven*, 12. *No reports*—Brandon*, Danby, Fair Haven*, Mount Holly, Rutland, Rutland town, Tinmouth, Wallingford, Wells, 9.

WASHINGTON. *Deposits*—Barre, East Montpelier (x), Marshfield, Moretown, Plainfield (x), Waitsfield, Waterbury, Worcester, 8. *None known to town clerk*—Barre town, Calais, Duxbury, Middlesex, Montpelier, Roxbury, 6. *No reports*—Berlin, Cabot, Fayston, Northfield, Warren, Woodbury, 6.

¹ See in this connection the statement of the State Geologist as shown on page 176.

WINDHAM. *Deposits*—Grafton (x), Guilford, Marlboro (x), Newfane, Rockingham (x), Stratton, Townshend, Vernon, Wardsboro, Westminster, Whitingham, 11. *None known to town clerk*—Athens, Brookline, Dover, Dummerston, Jamaica, Putney*, Somerset, Windham, 8. *No reports*—Brattleboro*, Halifax, Londonderry, Wilmington*, 4.

WINDSOR. *Deposits*—Andover (x), Baltimore, Cavendish, Chester, Ludlow, Norwich, Pomfret, Springfield, Weston, Woodstock, 10. *None known to town clerk*—Barnard, Bethel*, Hartford, Rochester, Sharon, Weathersfield*, Windsor*, 7. *No reports*—Bridgewater, Hartland*, Plymouth, Reading, Royalton*, Stockbridge, West Windsor, 7.

The statements shown above epitomize as follows:

County	Deposits known to town clerk	No deposits known to town clerk	No reports made by town clerk
Addison	15	4	4
Bennington	7	5	5
Caledonia	10	2	5
Chittenden	11	2	3
Essex	8	3	2
Franklin	7	3	5
Grand Isle	5	..	..
Lamoille	7	1	2
Orange	7	7	3
Orleans	6	3	9
Rutland	7	12	9
Washington	8	6	6
Windham	11	8	4
Windsor	10	7	7
Totals.....	119	63	64

Probably deposits are located in at least 30 towns listed in the "no deposit" or "no report" columns.

V. LOCATION AND DESCRIPTION OF DEPOSITS

ADDISON COUNTY

Bridport, No. 132. R. L. Heminway; 150 acres, average depth 3 feet; was heavily wooded, now carrying large decaying stumps. No. 133, James W. Pratt; swale meadow, average depth 3 feet; once heavily wooded. No. 134, Ditto; alder meadow, average depth 3 feet; never heavily wooded. (See plate III.)

Other deposits reported by town clerk (1905) are on farms of T. J. Butler, 25 acres; George D. Paine, 50 acres; William M. Grandy, George Sotlace, George St. John.

Bristol. Nos. 141-147. Bristol pond: (See Plate IV.) This pond is located two miles north of the village. Ice is cut in winter and an old ice road leads through the swamp to the water. This pond and surrounding formations constitute one of Vermont's largest transitional peat bogs. It is simply a matter of time when the water now in the basin will be displaced or absorbed by the enormous amounts of moss and accumulating silt. That the pond originally presented a much larger water surface is very evident from the general lay of the land, from the large swamp which surrounds it, and from the nature and depth of the deposited material. The pond is slowly turving over. A man's tread on the moss a few rods back from the water's edge causes the surface to vibrate. The pond itself is filled with a mushy deposit which comes within a foot or so of the surface. Pitcher plants and many varieties of mosses grow luxuriantly. The wide contour of the swamp presents growths of cedar, hemlock, tamarack and various shrubs. The peat is of a reddish cast. No. 141 was drawn from the edge of the swamp, No. 142 represents like material from the pond proper, No. 143 was taken at a point a short distance back from the pond, No. 144 was from the interior and Nos. 145, 146 and 147 represents the top, middle and bottom layers respectively of a cedar belt.

Cornwall. Town clerk reports (1905) deposits on the farm of John Holland, N. D. Muse, A. D. Parkhill, L. W. Peet, George Tully.

Monkton. No. 139. A. N. Baldwin, 50 acres, average depth 5 feet at edge; No. 140, Ditto; interior of bog. Part of the swamp has been filled to make a road bed for a public highway; No. 138, Clark area; partly woods and partly wild meadow lands; sample drawn from former.

Town clerk reports (1905) deposits on farms of W. H. Gee, 5 acres; C. A. Thomas, 12 acres.

Orwell. Town clerk reports (1905) deposits on farm of C. E. Abell estate.

Shoreham. Nos. 129-131. Shoreham swamp (See Plate V.) This tract is a mile square and, at time of sampling, was almost submerged. Little if any sphagnum moss grew, but reeds and rushes abounded. A wide belt of coarse swale grass surrounded the swamp, which was almost valueless for hay. The peat was reddish brown in color and seemed to consist chiefly of decayed wood fragments. If properly drained this area might develop a valuable peat bog. Several old wood roads exist which are used in the winter. No. 129 was drawn from an

entirely submerged interior area, No. 130 from a drier part near the center, and No. 131 from the swale belt at the contour near an old wood road.

Starksboro. Town clerk reports (1905) deposits on farms of O. W. Ferguson, F. J. Hanson, Isaac Harris, H. W. Hill, Thomas Hill, Celia K. Sayles, George Stokes.

Vergennes. No. 148. Booth estate; a very deep deposit near the roadside, two miles from the railroad station; dug and used extensively as a fertilizer; of quantity and quality sufficient to warrant utilization for that purpose; sample drawn from top of excavation. No. 149, Ditto; sample drawn from bottom of excavation.

Weybridge. Town clerk reports (1905) deposits on farms of J. A. James, G. R. Norton, L. O. Thompson, L. S. Wright.

Whiting. Town clerk reports (1905) deposits on the farms of C. B. Hubbard, H. C. Kelsey, Geo. Walker estate.

BENNINGTON COUNTY

Bennington. No. 151. Bald Mountain; sphagnum bog on top; sample consists of surface moss. No. 152, Ditto; sample consists of top peat. No. 153, Ditto; sample consists of bottom peat. No. 121, R. O. Gove; muck 3 feet deep at point of sampling; very deep in places. No. 150, Aaron Hill; reported to be very deep, but it did not prove to be so; of low value. No. 122, Frank Rice; area when sampled in grass; a large ditch occurs where the peat has been excavated (see Plate VI); surface black, underlying strata a dark reddish brown; sample drawn from top. No. 123, Ditto; sample drawn from bottom. No. 161, John Rockwood; 4 acres; much has been excavated for agricultural uses, leaving a small pond; material a rich black muck, shading off to brown at the bottom of the deposit; sample drawn from top. No. 162, Ditto; sample drawn from bottom. No. 201, Eugene West; 5 acres; 3-4 feet deep; wooded and partly pasture; material has been used extensively as fertilizer by owner and by neighbors; the ditches made in excavating are gradually filling; the deposit is now comparatively dry and could be readily drained; sample drawn from top layer, a rich black muck. No. 202, Ditto; sample drawn from bottom layer, which possesses a peculiar brownish luster, readily apparent when dry; about 1 foot thick, showing plainly the presence of mosses in a state of almost complete decay.

Town clerk reports (1905) deposit on Charles Rockwood estate.

Manchester Center. No. 118. F. D. Giddings; 4 acres, 3 feet deep;

located near fair grounds; at first sight apparently a peat of good quality, consisting of partly decomposed vegetable matter; upon drying, however, it discloses many quartz-like pebbles, which notably raise the amount of ash and lower its quality.

Manchester. No. 127. Thompson; not a sphagnum bog, but, apparently, ordinary meadow land; sample drawn from top layer of black muck. No. 128, Ditto; sample drawn from bottom layer, containing much partially decayed yellowish wood.

Pownal. Town clerk reports (1905) large sphagnum bog.

Searsburg. Town clerk reports (1905) 5 acre deposit on farm of Eliot Bishop.

Shaftsbury. No. 266. Peleg Cole estate; 7 acres; mostly wooded; located near Rutland railroad; very deep reddish brown muck and peat; sample drawn from top near edge of swamp. No. 267, Ditto; sample drawn from layer below the top. No. 268, Ditto; sample drawn from still lower near the edge. No. 269, Ditto; sample drawn from the interior of swamp.

Sunderland. No. 126. Jerome Hill, 1 acre. The so-called "sink hole," a large bowl-shaped depression in the center of a good meadow, in which various species of trees grow; covered with a dense thick sphagnum layer, perhaps 18 inches thick, beneath which lies a dense tough black layer of roots, under which logs are found. Tradition has it that when this section was cleared of first growth, logs were shoved lengthwise into this crater-like opening, until it was substantially filled. No genuine peat was encountered in the excavation. The material analyzed, however, was organic in its nature.

CALEDONIA COUNTY.

But few reports being received from Caledonia county of deposits of any size, no visitation was made. Town clerks reported (1905) that deposits were located on properties as follows:

Barnet. R. B. Gammell, Jas. Gilfillan, 2 acres.

Danville. E. R. Mackey, Geo. A. Stoddard, H. J. Williams.

Ryegate. Ora Bishop, Mrs. M. E. Lane, W. T. McLam, Jackson Smith.

Waterford. W. O. Greely.

CHITTENDEN COUNTY

Bolton. Town clerk reported (1905) deposit on farm of E. E. Pierce.

Charlotte. No. 296. Miss Genevieve Horsford, 25 acres, 2 feet deep; extends to adjoining farms; vegetation consists of wild grasses.

cranberries, mosses and, on a small section, young soft maples. The deposit has been used in cranberry culture and has likewise been used upon the farm for fertilizer and sold to outsiders. The area could be drained without large expense. Situated five and a half miles from Charlotte railroad station, six miles from Shelburne; sample represents top of first excavation. No. 297, Ditto; sample represents bottom of first excavation. No. 298, Ditto; sample represents top of second excavation. No. 299, Ditto; sample represents middle of second excavation. No. 300, Ditto; sample represents bottom of second excavation. (See Plate VII.)

Colchester. No. 207. Barstow estate at Colchester Point, situated near Rutland railroad; area several acres; principal vegetation consists of sphagnum mosses, blueberry bushes, pitcher plants, white birches, reeds, rushes; covered with a dense surface formation of roots; deposit very deep, but, owing to excessive moisture, samples could not be taken below two and a half feet. It would be an expensive task to drain this bog. Sample drawn from near top. No. 208, Ditto; sample drawn two and one-half feet down.

Essex. Town clerk reports (1905) deep deposit on farm of D. C. Slater, 2 acres.

Hinesburg. Town clerk reports (1905) deposits at Beaver brook and LaPlatte valley.

Jericho. No. 213. Jordan Brothers, 6 acres, 12 feet deep; meadow bog; top layers coal black in color, deeper deposits brownish or yellowish, due to abundance of soft decayed wood and moss; very accessible, well drained, good arable land; produces large yields of corn, but light hay crops; a similar deposit of the same size and depth adjoins it, on the farm of H. L. Murdock; sample drawn from top. No. 214, Ditto; sample drawn from middle of deposit. No. 215, Ditto; sample drawn from bottom of deposit.

No. 216. Formerly owned by Dr. B. H. Stone; a veritable cranberry swamp, thickly covered with blueberry bushes, pitcher plants, many mosses, skirted with tamaracks, maples, fallen logs, upturned stumps, etc.; in the center the deposit is a brownish pulp intermixed with roots; at four feet deep, the character of the material is unchanged; at the edge of the clearing it is darker brown in color and in a state of complete decay; a highly inaccessible bog; sample drawn from top layer of moss. No. 217, Ditto; sample drawn at edge of the clearing. No. 218, Ditto; sample drawn from the wooded portion.

Town clerk reports (1905) deposits on the farms of D. D. Bicknell, Edgar Hoyt, E. H. Nash, J. A. Leary, Sweeney Brothers.

South Burlington. Nos. 64-82. L. A. and A. A. Drew, 100 acres.

In 1901 the late Mr. L. A. Drew sent to the Station for analysis two samples of peat drawn at his one hundred acre South Burlington swamp. The analysis showed so little ash and such a high organic matter content that the owner queried whether the bog might not be made a source of fuel. No steps were taken, however, to install a fuel plant in view of the undeveloped nature of the industry in this section, the high initial cost of the machinery and the considerable outlay of ready capital which would be necessary. However, this location was borne in mind in connection with the general survey of the deposits of the State and a special study was made of this particular deposit. The convenient location as well as the size of this bog made it peculiarly adapted to this purpose.

A preliminary examination made in the late fall disclosed a typical cranberry bog, with its water pitchers and jack rabbits, over which were scattered many bunches of pines, spruces and balsams as well as dense copses of tamaracks and other small shrubs. A shrub resembling a huckleberry occupied the unwooded space together with a dense mat of moss of many kinds, especially sphagnum. On the surface of this moss wild cranberries were growing.

The peat in this bog is mostly of a mossy type (Plate VIII), very different in structure from that found throughout Grand Isle. Excavations were made and samples taken from the four corners, along the borders and special attention was given to one of the clearings.

Nos. 64-65. Top and bottom respectively of deposit at the southeast corner, thickly wooded. No. 66. Northeast corner, one foot deep. Sod covered with marsh grass and heavy timber. Nos. 67-69. Top, middle and bottom respectively of excavation at northwest corner under a thick tamarack copse. No. 70. Along the east border.

The remaining samples were taken from the clearing which extends into the southwest corner of the swamp. Nos. 71-73. Top, middle and bottom respectively of first excavation. Nos. 74-76. Top, middle and bottom respectively of second excavation.

The third excavation, the largest made, was about ten feet in circumference and five feet in depth, extending to the clay sub-soil. No. 77. Top just beneath the superficial moss layer. (See Plate VIII.) Nos. 78-81. Intermediate layers down to 81, which seemed to be pure clay and hence was not analyzed. The top peat was brown, the other sam-



PLATE V.—A view in Shoreham swamp in Shoreham, Addison county; a large and densely wooded area. (See pages 180, 204-205, 223).



PLATE VI.—A ditch dug in a deposit in Bennington, Bennington county showing the method of drainage. (See pages 181, 204-205, 224).



PLATE VII.—Illustrative of methods and implements of sampling, the depth of taking samples, etc., Horsford deposit, Charlotte, Chittenden county. (See pages 177, 182-183, 206-207, 224-228).

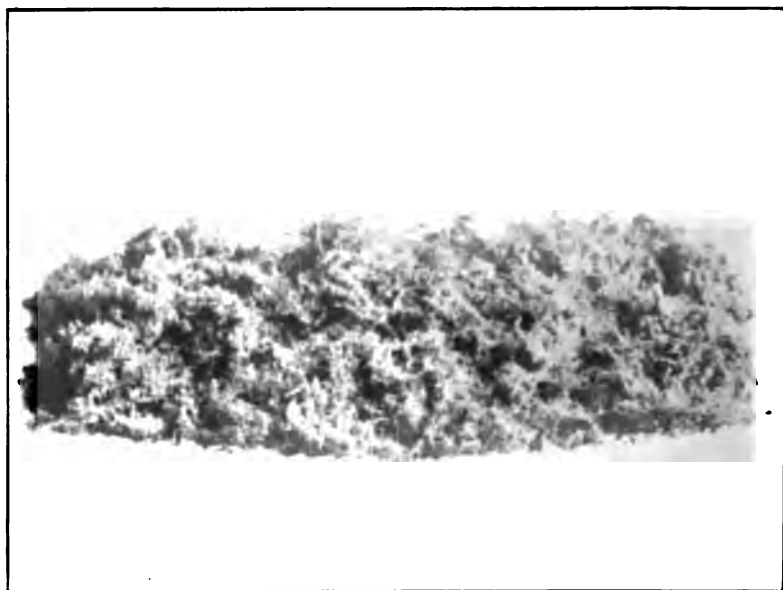


PLATE VIII.—Peat moss. Peat in its early stages, not disintegrated. (See pages 168, 172, 184, 186).



PLATE IX.—Peat briquettes from the Drew deposit, South Burlington, Chittenden county. These were made of such slabs as are shown in Plate I. They are ready to burn, and make an intense heat. (See pages 160-163, 185).



PLATE X.—Swale meadow on Nichols farm in Westford, Chittenden county. The hay is cut, but could not be harvested on account of too much water. (See pages 185, 208-209, 226).



PLATE XI.—Extensive deposit on the Hill farm, Isle La Motte, Grand Isle county. One of the largest, and, from the point of view of plant food, richest deposits in Vermont. (See pages 189, 210-211, 228).



PLATE XII.—A deposit in Benson, Rutland county, underlaid with marl. Illustrative of pocket type of deposit. (See pages 193, 214-215, 232).

ples grading in color to 80, a light gray, doubtless due to clay admixtures. No. 82. A small sample drawn at the lowest depth in this vicinity.

The peat in this bog seemed thoroughly saturated, yet excavations did not fill with water. Three large lots were secured for fuel tests. They were stored in bran sacks for several days and then compressed into briquettes, a small wooden box being used as a mold. These remained in a damp, soggy condition for a while, but later were dried out, becoming so hard as to emit a resonant sound when hammered. A few of these blocks when burned over coal produced an intense heat. (See Plate IX.)

Town clerk reports (1905) deposits on farms of Alec Blair, C. C. Bliss, Wilbur Hall, J. P. McKenzie, C. V. Richardson, Thomas Ryan, G. B. Wheeler estate, H. H. Wheeler. One of these, on Thomas Ryan's farm, is 10 acres in extent and 10 feet deep.

Westford. No. 209. L. C. Nichols, 20 acres, 10 feet deep; a basin surrounded by hills on all sides; used as meadow land; the tract has once been drained inadequately, some of the ditches being still well preserved; principal vegetation consists of mosses, rushes, cattails, swale and wild grasses and shrubs; sod tough and thick; beneath it, fragments of timber and decaying branches; deposit very deep, but water prevents excavating below five feet; upper layer black, deeper layers changing from brown to gray, indicating probably clay sub-soil; sample drawn from the top of the deposit. No. 210, Ditto; sample drawn about one and one-half feet down. No. 211, Ditto; sample drawn 4 feet down. No. 212, Ditto; sample drawn 5 feet down. (See Plate X.)

Town clerk reports (1905) deposits on farms of H. F. Jackson, Thos. L. Orton, Rogers and Powell, Thos. B. Tyler.

Williston. Town clerk reports (1905) deposits on farms of W. A. Bliss and D. I. Talcott.

ESSEX COUNTY

Circumstances prevented a survey of the peat deposits of this county, which doubtless exist in large numbers. Town clerks have reported (1905) as follows:

Brunswick. Jas. O'Dowd, A. W. Smith, 1 acre, 4 feet deep.

Canaan. Chas. Morrill.

Concord. A. J. Barnet, Dana Rivers, Abner Rutledge, 3 acres, 2 to 10 feet deep; Wm. Williams, Jr., 1 acre.

Granby. Napoleon Fields, Fred Jones, C. W. Matthews, Joseph L. Wells, 75 acres.

Lemington. O. E. Covell, 4 acres; A. T. Holbrook, 3 acres; C. R. Holbrook estate.

Lunenburg. John N. Cole, 5 acres; F. N. Pierce, 5 acres.

Maidstone. Wayne Cobleigh, 2 acres.

FRANKLIN COUNTY

Fairfax. Town clerk reports (1905) deposits on the farms of Douglass Buck, D. G. Danforth, W. N. Daniels, I. E. and W. H. Farnsworth, D. J. Norton, 3 acres; N. G. Ufford.

Franklin. Nos. 154-156. Cranberry marsh, 200 acres, from 5 to 20 or more feet deep. This is a remarkably fine deposit of unripe peat and peat moss. Its interior growth consists of stunted spruces, tamaracks, and pitcher plants in abundance, embedded together with two or three varieties of cranberries in immense quantities of the red sphagnum moss. No change in the character of the material is noticeable as one digs or probes downwards. It is always the same semi-decayed moss saturated with water and permeated with fibrous rootlets. There are many treacherous holes in the bog and near its center are several so-called bottomless ponds, containing yellow water lilies and a species of fish known as "bull pout." Presumably the whole formation was at one time a large pond. The region is now inadequately drained by a small stream. Until drainage becomes more completely established, its contents cannot be converted into peat. In its present state, however, it is perhaps the most extensive deposit of good peat moss in Vermont. It would furnish abundant raw material for a moss litter establishment or a paper stock factory. Its location, some six or seven miles from the nearest railroad station, militates against its use for this purpose. The red hue of the moss is pronounced. Several attempts were made to bleach it, using the more common bleaching agents, but without success. Nos. 154-155, lower and upper layers respectively of the peat moss; No. 156, the reddish brown peat from the periphery of the marsh. (See Plate VIII.)

Nos. 157 and 158. J. W. Grant, Willard farm, 50 acres. This deposit has been worked quite extensively by Mr. John Webster for fuel purposes (see pages 158-163.) This tract of land is located about three miles from Franklin village by road, is an old beaver meadow and was once heavily timbered. It is quite dry and covered with small trees and shrubs. The peat as excavated was black at the top, brown near the middle, and liver-colored near the bottom. The peat deposit is six

feet deep and overlies a deposit of shell marl. The bog was not drained previous to the cutting done by Mr. Webster, but he agreed to dig ditches and drain the area for the material excavated. These ditches were made 7 or 8 feet wide and a few rods apart and the peat was taken out clean. Mr. Webster built a drying shed for \$25, and the first year sold \$50 worth of peat. The next year, however, he sold hardly any, for his customers found that the ash pan in the ordinary wood stove was far too small to accommodate the ashes from even a half day's burning. He found that the peat when disintegrated and put in molds, dried much quicker than did that cut in blocks and left intact to dry in the air. (See Plates IX and XV and figures 1 to 3.)

Town clerk reports (1905) deposits on farms of Bates, Wilder and Marsh, McDermott, J. H. Pierce, H. C. Pomeroy, Edw. Powers.

Highgate. No. 230. Jewett farm, about 50 acres; deposit very deep and of good quality; principal vegetation consists of various trees, shrubs, cattails, grasses, sphagnum mosses, pitcher plants; reddish brown decayed wood and moss. At one time this property was purchased by a company organized to make peat fuel, but was not successfully operated. Apparently the place could be drained at small expense, there being two areas with a water shed between them. The region was never systematically ditched. One portion of the tract is now an old stump pasture, but the main portion is not frequented by cattle. The farm was sold to its present (1907) owner at a nominal figure. Formerly two or three rights for a term of years were sold to different parties for the manufacture of peat fuel. The sample drawn represents top of layer. Nos. 231 to 234, Ditto; samples represent successive layers downwards.

Richford. Nos. 235-237. Moses Pattee and Son, 40 acres, 15 feet deep; a deep deposit of peat and muck, the peat showing decayed wood and grass roots. A pole 18 feet long was run down, but the bottom was not reached. The material has been used to a small extent as a fertilizer; area is partly in meadow and partly wooded; samples were drawn from top downwards in the middle portion. Nos. 238-240, Ditto; samples drawn from wooded section from top downwards.

Town clerk reports (1905) deposit on the farm of J. B. Mudgett, 10 acres, 9 feet deep.

Sheldon. Town clerk reports (1905) deposits on farms of D. A. Smith, 6 acres; Silas F. Ovitt, 20 acres, 4 feet deep.

Swanton. Town clerk reports (1905) deposits on farms of J. A. Barney, C. E. M. Bullard, D. G. Furman (100 acres), H. C. Stilphen, Arthur Suprenant.

GRAND ISLE COUNTY

Alburg. No. 52. Lyman swamp on United States and Canada line; a very extensive peat deposit of the decayed wood type; recently cut over and bearing a magnificent new growth of young cedars; partly drained by ditch through center. Underneath a peat deposit from 6 to 10 feet deep lies a heavy deposit of shell marl. A fire brick company negotiated for this piece some time ago, but no sale resulted; sample drawn from the edge of the young cedar swamp. No. 53, Ditto; sample drawn from bottom layer of young cedar swamp. No. 54, Ditto; sample drawn from top layer in cedar swamp.

No. 55. Canadian line swamp near international boundary; deposits are very deep, as was found when excavations were made for the road bed of the Canada Atlantic division of the Grand Trunk railway; sample drawn from edge of swamp, which, at the time of digging, was under 2 feet of water. No. 56, Ditto; sample drawn from interior of swamp, just beneath decaying underbrush and moss. No. 58, Ditto; sample consists of surface moss, heavily saturated with water (partial analysis, p. 236). No. 57, Ditto; average sample drawn from another section, in neighborhood of the drainage ditch (partial analysis, p. 236).

No. 50. Mott farm; cattail swamp, located half a mile from the Canada line; sample drawn from the top layer. No. 51, Ditto; sample drawn from the bottom layer.

Grand Isle. No. 20. Adams marsh, near Adams Landing; shallow deposit.

No. 14. Davis farm near R. E. Samson's; covered with large and partly decayed stumps; a common black muck scarcely 1 foot deep (partial analysis, p. 237).

No. 5. Perley Gordon; marsh situated on lake shore; vegetation consists of coarse marsh grass and cattails; excavation five feet deep made near the lakeside (partial analysis, p. 237).

No. 17. A. H. Hyde; black muck; sample drawn just over fine bed of shell marl.

No. 13. E. J. Parker; small bog near lakeshore, subject to spring overflow; common black muck, containing many small shells.

No. 1. Mrs. Lucy Pearl; swamp near lakeshore, connected therewith by a narrow channel; vegetable growth consists of aquatic plants, cattails, swale grass, mosses, water lilies and divers trees; sample taken about 2 feet down (partial analysis, p. 237). No. 2, Ditto; sample drawn from center of swamp; much blacker than one (partial analysis,

sis, p. 237). No. 3, Ditto; sample drawn from portion of swamp overgrown with cedar; hardpan located 2 feet below surface (partial analysis, p. 237). No. 4, Ditto; sample drawn from edge of cattail bog, beside the channel; excavation 5 feet deep (partial analysis, p. 237).

No. 15. Crate Reynolds cedar swamp; sample drawn near edge, 1½ feet deep. No. 16, Ditto; sample drawn from interior, from excavation 2½ feet deep.

Isle La Motte. No. 59. H. H. Hill farm (Mr. Phelps); this marsh divides the island into two parts; sample represents turf peat at a point where it was very thick. No. 60, Ditto; sample drawn at very edge of swamp; clay one foot below the surface (partial analysis, p. 237). No. 61, Ditto; sample drawn from bottom peat, where turf was very thick. No. 62, Ditto; sample drawn from middle of swamp, with but little sod. No. 63, Ditto; sample drawn from a deeper layer in the same pit as 62. (See Plate XI.)

North Hero. No. 41. Allen's Creek; six acre marsh near village; sample drawn from the bottom of 6 foot excavation (partial analysis, p. 237). No. 42, Ditto; sample drawn from top of 6 foot excavation (partial analysis, p. 237). No. 43, Ditto; sample drawn from interior of marsh.

No. 36. W. B. Dodds; 100 acre marsh bordering on the lake, covered with alders, cattails, and divers trees; sample drawn from portion of the marsh under water. No. 37, Ditto; sample drawn from top layer of excavation 6 feet through the interior of the marsh. No. 38, Ditto; sample drawn from bottom layer of excavation 6 feet through into interior of marsh. No. 39, Ditto; sample drawn in the dryer portion of swamp, underneath thick sod. No. 40, Ditto; sample drawn from underneath the thicker sod.

No. 44. John Dubuc; 20 acre swamp; sample drawn from near edge. No. 45, Ditto; sample drawn from bottom of excavations in interior of swamp. No. 46, Ditto; sample drawn from top, interior of the swamp.

No. 47. Macomber; sample drawn from inshore near lakeside (partial analysis, p. 237.) No. 48, Ditto; (partial analysis, p. 237.) No. 49, Ditto; sample drawn from wooded part.

Town clerk reports (1905) also deposits on farms of: Robert Atkins, 20 acres; Mrs. C. E. Darrow, 15 acres; Mrs. Giles Harrington, 20 acres; H. B. Knight, 10 acres; Rutland Railroad Company, 20 acres.

South Hero. No. 32. From marsh on Allen creek, near railroad

station; average sample near surface together with some roots (partial analysis, p. 237). No. 33, Ditto; an upper layer further out in the marsh (partial analysis, p. 237). No. 34, Ditto, a bottom layer further out in the marsh, 2 feet deep (partial analysis, p. 237). No. 35, Ditto; from a wooded portion of the marsh (partial analysis, p. 237.)

No. 6. S. P. Gordon estate; a portion of the famous Pearl swamp, which covers about 100 acres; brown and fibrous. The owner has made extensive use as a fertilizer, more so than anyone else in the county. The Gordon section of the swamp is covered by a growth of pine, tamarack, spruce, maple etc.; sample is an average from the first excavation. No. 7, Ditto; sample drawn from top of excavation. No. 8, Ditto; sample drawn from bottom of excavation. No. 9, Ditto; sample taken from extreme bottom of the excavation, apparently an ordinary blue clay substratum and, consequently, only partially analyzed. No. 10, Ditto; sample drawn from bottom layer of peat, from another excavation. No. 11, Ditto; sample drawn from top layer of peat from the same excavation. No. 12, Ditto; average sample drawn from a third excavation.

No. 30. Edward Phelps; sample taken under one foot of white sand and from a very thin layer; bog located near the lakeshore, whence the sand (partial analysis, p. 237.)

No. 31. From a small stump swamp near 30; deposit only 4 inches deep.

Nos 21 to 29 inclusive. Alson Landon: Round pond. This oblong pond, an acre in area, is an interesting example of the formative stage of cumulose deposits of soil. It is located near the lake and each spring is overflowed thereby. It is skirted by a growth of black ash and other trees, then by coarse reeds and cattails, and lastly by a growth of rushes, the roots of which are slowly encroaching upon the center of the pond, forming an overhanging reef-like structure, strong enough to hold one's weight, but trembling beneath one's tread. The way must be cautiously chosen to the edge of the pond, stepping from bog to bog. These bogs change quite abruptly to single reed root stalks which help make up the thin reef. The pond seems nearly filled with a soft mushy deposit. Myriads of aquatic plants known locally as water buttercups grow, in some places so closely as to tinge the water with green. The pond apparently has no bottom. Long spliced poles thrust downwards do not meet resistance. A bed of reddish brown peat, which darkens on exposure to the air, surrounds the pond. Its

bottom layer was not reached for sampling. The deposit on the outer edge of the swamp, two feet deep, was blacker than the residue. The excavations when made rapidly filled with water.

Nos. 21-23 were taken on the fringe of the wooded portion surrounding the pond and represent respectively the bottom, middle and top layers of an excavation 3½ feet deep (partial analysis, p. 237). No. 24, a brown pond silt of a fishy odor, due to the many lake fish which find access when the overflow occurs and which, stranded there and entrapped, die and decompose. No. 25, a few feet back from the pond among the bogs. Nos. 26-29, from an excavation in the interior of the black ash swamp. No. 26, three feet below surface. No. 27, just beneath the sod. No. 28, the sod. No. 29, at the extreme bottom of the excavation.

LAMOILLE COUNTY

Cambridge. Town clerk reports (1905) deposits on the farms of H. W. McNally and Earl Prior.

Elmore. Town clerk reports (1905) deposits on the farms of O. D. Bacon, F. H. Griswold, Charles Merriam, C. T. Sibley, F. L. Slayton.

Johnson. No. 219. B. A. Hunt; area 100 acres, 7 feet deep; cranberry marsh; a highly inaccessible bog, covered with sphagnum mosses; no pitcher plants such as are commonly seen in such places were observed. Near the center three small ponds are slowly filling up with silt and are gradually being surrounded with dangerous reefs; sample drawn from moss in clearing. No. 220, Ditto; silt from same. No. 221, Ditto; sample drawn from the edge of the clearing. No. 222, Ditto; sample drawn from timberland, at top of deposit. No. 223, Ditto; sample drawn from timberland, at bottom of deposit.

No. 225. B. A. Hunt; Sterling pond, a separate basin about 100 rods distant from above deposit. The pond is gradually filling with silt of a reddish color. Around its edge lies a deposit of reddish peat, below which a debris of tree branches prevents further digging. Sample represents the peat near the water's edge.

Nos. 226-229. Edward Magoon; a large muck bed, 6 to 12 feet deep, beside the public highway; 8 to 9 acres in area and used as meadow land. It has been ditched for drainage; raises a lighter crop of hay than formerly. A thick turf of moss and grass roots at the surface, below which lies the reddish muck and, yet deeper, a thick layer of grass roots, with a peat of a grayish color at the bottom. Samples represent respectively successive layers from the top downwards.

Morristown. Town clerk reports (1905) deposits on farms of Mrs. E. H. Allen, I. F. Chamberlain, M. M. Jackson, H. N. Olmstead, F. M. Small, Levi S. Small, F. A. Strong.

Stowe. Town clerk reports (1905) deposits on the farms of W. G. Clark and W. F. Harris, and on Mount Mansfield.

Wolcott. Town clerk reports (1905) deposits on the farms of Jason E. Hunt, Didas Lapaline, A. Scott.

ORANGE COUNTY

Thetford. Town clerk reports (1905) deposits on the farms of G. A. Chamberlain, J. T. Brooks, R. Harvey, H. F. Emery.

Tunbridge. Town clerk reports (1905) deposits on the farm of C. E. Brown.

Vershire. No. 256. E. P. George estate; large swamp containing, however, no great depth of peat. Another deposit on the same estate was at one time used as fuel in the smelting of copper ore.

West Fairlee. No. 253. Knight Brothers; 20 acres of very deep muck; wild meadow land near the public road, partially covered with coarse grass, with some fine marsh grass, and in places thickly dotted with old stumps; wild grasses and mosses abound; partly drained by a deep ditch, to construct which it was necessary to do considerable blasting; sample drawn from below the coarse grass areas. No. 254, Ditto; sample drawn from the top layer, where the grass was short and fine. No. 255, Ditto; sample drawn from the bottom layer, where the grass was short and fine.

Williamstown. No. 101. Wm. C. Pratt; 30 acres of very deep black muck, turfed over with wild meadow grasses and mosses producing an average hay crop; sample was a mixture of material from the various depths, the excavation being made in the marshy area. No. 102, Ditto; sample drawn from the top of the second excavation, taken at some distance from the first. No. 103, Ditto; sample drawn from the bottom of a second excavation taken at some distance from the first.

ORLEANS COUNTY

Albany. No. 248. Vance estate; an old meadow, 100 acres in extent, which appears in the distance to be, and in reality is, a wild overgrown swamp, set in a natural basin among the hills. Spruce, hemlock and tamarack abound; blueberry bushes and thousands of pitcher plants grow in its water-soaked areas. Sample represents the top layer of the excavation made in the clearing. No. 249, Ditto; sam-

ple represents the middle layer of the same excavation. No. 250, Ditto; sample represents the bottom layer in the same excavation. No. 251, Ditto; sample represents the top layer in an excavation in the fairly well wooded section. No. 252, Ditto; sample represents the bottom layer of the latter excavation.

Town clerk reports (1905) deposits on farms of J. A. Brown and Burney Dyar.

Derby. Town clerk reports (1905) deposit on farm of Herbert B. Tice, 1 acre.

Glover. No. 241. From the bed of Runaway pond on the farm of Fred Corlis, eight miles from Barton, 50 acres, from 1 to 40 feet deep. One hundred years ago this area was covered by a large pond with its outlet flowing towards Greensboro and into the Lamolille river. The soil forming the sides of its basin was of the nature of quicksand. One day when two men with shovels tried to turn a little water in the direction of Glover, the whole bank gave way, resulting in the draining of the entire pond into the Black river and thence into Lake Memphremagog. Today its site is marked by an immense muck bed near the main highway to Greensboro Bend. The tract has been drained in its higher portions and produces good hay. As one walks over or jumps up and down upon the thin sod covering the lower and softer portions, the surface over large areas quakes and trembles, great undulating waves or ripples being set in motion. A thin stratum of brown peat underlies the sod, below which occurs a mass of dark gray mush of a cement or mortar like consistency. It was impossible to dig to any depth, for the soft mush promptly fills in from the bottom and sides of the excavation. This same deposit predominates below after the first few inches in the drier portions. The owner has not tried to drain the whole piece. When exposed to sun and air, the deposit becomes tough and leathery and cleaves apart in layers. Barnyard manure does not appear to benefit the soil, but the use of wood ashes seems advantageous. But a small area has been reclaimed, the residue bearing only mosses, shrubs, a few trees and marsh grasses.

RUTLAND COUNTY

Benson. No. 135. Strong Brothers; 40 acres; so-called sage brush bog, a deposit of muck and small white shells, intermingled; the only deposit of this character observed by the writer (F. M. H.). The material, were it not for the shells, would prove an excellent source of fuel, and in its present condition, a mixture of organic matter and

lime compounds, principally carbonates, would seem admirably suited to manurial purposes. (See Plate XII.)

Town clerk reports (1905) deposits on farms of W. S. Bascom, J. P. Clark and H. R. Jones.

Hubbardton. Town clerk reports (1905) deposits on farms of E. E. Giddings.

Ira. Town clerk reports (1905) deposits on farms of H. C. Fish, Leonard Fish, Lyman W. Fish, J. C. Parker, S. L. Peck, E. B. Perry.

Mendon. Town clerk reports (1905) deposits on farms of A. W. Perkins and H. H. Shedd.

Poultney. Town clerk reports (1905) deposit on farm of Sarah Martin.

West Rutland. Town clerk reports (1905) deposits on farms of Jay Cook, Wm. Dempsey, M. Kennedy, Andrew Manly, Fred Raymond, True Blue Marble Co., Vermont Marble Co.

WASHINGTON COUNTY

Barre. Town clerk reports (1905) deposit on farm of Welch & Sons; 5 acres, 6 feet deep.

Marshfield. G. L. Dwinell; 40 acres; said to be very deep; so-called beaver meadow; tamarack swamp and cleared land. No. 106, from top. No. 107, from bottom of excavation located in cleared portion. The bottom of the deposit could not be reached with the implements at hand.

J. A. Ennis; 30 acres. A deep reddish brown peat; used freely as a fertilizer, the excavated portions being now occupied by a pond of considerable depth and area. No. 108, from top of an excavation. No. 109, from bottom of an excavation. (See Plate XIII.)

Moretown. Town clerk reports (1905) deposit on farm of F. A. Howes.

Waitsfield. Town clerk reports (1905) deposit on farm of J. A. Berry.

Waterbury. Town clerk reports (1905) deposit on farm of A. E. Batchelder, 7 acres, 7 feet deep; George Randall, 15 acres.

WINDHAM COUNTY

Guilford. Town clerk reports (1905) deposits on farm of E. M. Angier, 5 acres; Miss M. Coombs, 3 acres, 4 feet deep; Geo. W. Franklin, 10 acres, 4 feet deep; Fred A. Thomas, 2 acres.

Newfane. Town clerk reports (1905) deposits on farm of Joel Grout, 30 acres, 10 feet deep; P. P. White.

Stratton. No. 271. H. P. Forrester, 10 acres, 4 feet deep; so-called mud pond, a large and probably shallow pond with muddy bottom overlying a bed of rock, surrounded by a shallow layer of peat. The pond is enclosed in timberland and contains many dead logs.

A. J. Pike. These peat lands, located in Stratton, are among the most extensive in Vermont. They lie in the midst of valuable timberland and cover many acres. Mosses and pitcher plants abound, as do, also, bear, deer and other wild animals. There are three distinct lots separated from each other by timberland. These are: first, the "cranberry marsh"; second, the "reed meadow"; and, third, the "huckleberry meadow." The deposits are very deep. The cranberry marsh is typical. A "bottomless pond" occupies its center, which is gradually filling in. The peat from this particular bog seems "riper" than that found in any other bog of the same kind in the State, it being blacker and more fully decomposed. The property lies two miles from human habitation. An old wood road leads into the swamp, which can be used only in winter, it being too soft for summer use. The owner thinks the bog could be drained.

No. 272. Top moss from the "cranberry marsh."

Nos. 273 and 274. Deeper layers in succession from the same.

Nos. 275-278. Successive layers from top downwards of material from the "reed meadow."

No. 279. From the "cranberry meadow."

Townshend. Town clerk reports (1905) deposit on farm of Fred M. Watson, Henry C. White.

Vernon. Town clerk reports (1905) deposit on farm of F. W. Scott, 2 acres.

Westminster. David Taylor; consists of about 50 acres of very deep muck. Part of the area has been drained and plowed and there are numerous ditches and cross ditches which have filled in, but which are now reopened. Unlike any other deposit examined, a thin layer of blue clay was encountered at a depth of five feet, under which peaty looking material was found to great depth. The ash content as found by analysis was surprisingly large. The material seemed when excavated to be a high grade peat. Doubtless the clay had more or less completely permeated the peat throughout the deposit. The material was brown when dug, but turned black in a very few minutes when exposed to air. The land is thickly overgrown with thoroughwort and coarse swale grasses, which stand as high as one's waist. A main ditch runs diagonally through the bog to the river three-quarters of a mile away. At its right—when facing the river—the soil seems to

be in better cultivation, though very wet. The owner had to ditch across a neighbor's field to partially drain his bog, but this ditch brings up sharply at right angles with the road bed of the Boston & Maine railroad. At the time of making the survey (1907) arrangements had not been perfected whereby this difficulty could be avoided. The bog is very accessible, being very close to the highway and railroad. (See Plate XIV.)

Nos. 280-286. From the upper end of the deposit the different layers successively from top to bottom, No. 285 being the layer of clay mentioned above.

Nos. 287-288. From an excavation in the center of bog, 287 being the middle layer and 288 the layer just below the blue clay formation.

Town clerk reports (1905) deposits on farm of G. P. Ellison, Martha Watkins.

Whittingham. Town clerk reports (1905) deposit on farm of Mrs. A. M. Boyd, 10 acres, 10 feet deep; C. S. Chase, 5 acres; G. W. Kentfield, 50 acres.

WINDSOR COUNTY

Baltimore. Town clerk reports (1905) deposit on farm of G. A. Bridges, 10 acres, 6 feet deep.

Chester. John A. Chandler and Irving Clark; adjoining farms; nearly 50 acres of very deep muck and peat. The place has been drained and part of it is now under good cultivation. The drainage, however, is inadequate and many of the ditches are filled in or overgrown. A foot or so of rich black loam forms the top layer in the best drained sections and moss in the other parts. In one corner of Mr. Clark's portion a large "muck hole" is filled with water caused by excavation. Mosses and sorrel are coming in.

Nos. 289-292. The various layers from top to bottom on the Chandler area. Nos. 293-295, Ditto, on the Clark area.

Ludlow. Nos. 160, 115-117. L. W. Barton (leased bog); moss and top, bottom and middle respectively of an excavation in a typical sphagnum bog of two acres' area; excavation six feet deep; about five miles from Ludlow railway station towards Tyson. The dominant vegetation consists of moss, pitcher plants and shrubs (largely heaths). The surface layer is composed of sphagnums, below which lies a tough, resistant layer of fibrous roots and, yet lower, a partially decomposed moss, gradually shading off into brownish peat. The peat from this bog has been successfully used for fuel and other purposes. At the

date of sampling large quantities had been thrown out in heaps and had weathered to a fine powder.

Norwich. Town clerk reports (1905) deposit on farms of A. C. Davis, 3 acres; T. A. Hazen, 4 acres; S. A. Johnson, 3 acres; Chauncey Smith, 4 acres.

Pomfret. Town clerk reports (1905) deposit on farms of Chas. A. Bushnell, H. W. Bushway.

Springfield. Town clerk reports (1905) deposit on farms of F. E. Cutler, 8 acres; P. S. Dutton, 12 acres; M. J. Griswold, 20 acres; H. H. Phillips, 7 acres.

Weston. Town clerk reports (1905) deposit on farms of J. H. Taylor, L. J. Woodcock.

Woodstock. No. 159. Billings Farm. A rich deposit of peat had been excavated for the purpose of making a large pond. The peat had been cut in large pieces and thrown out on the bank. The sample was taken from one of these large fragments. It was distinctly of the moss type, and, though the material has been weathering in the open air for years, it appeared hardly drier than peat just taken from the bog. The excavated material had been used chiefly as a fertilizer.

V. ANALYSES OF VERMONT DEPOSITS

CONCERNING THE TABULATIONS PAGES 204-220

The following statements as to the tabulated matter on pages 204-220 may serve to make more clear, both to laymen and to others, the meaning of the data. The description follows the columns from left to right.

1. *Station number.* A laboratory identification number. Samples 1-82 were drawn in 1904; 101-162 in 1905; 201-300 in 1907.

2. *Name.* The name of the party owning or occupying the premises at the time at which the sample was drawn.

3. *Description.* A brief characterization of the deposit. For more detailed description see matter on pages 179-197, which is arranged, as are the tables, alphabetically by counties, by towns in counties, by names within towns.

4. *Area.* Approximate area in acres, as reported by the owner, of the tract which the sample is assumed to represent.

5. *Depth.* Approximate depth in feet of the deposit, as reported by its owner or, more commonly, as determined by one of the writers (F. M. H.).

6. *Location of sample.* T, top of deposit; M, middle of deposit; B, bottom of deposit; A, average sample representing entire depth. In cases where two or more M's occur in sequence the first represents the upper, the second and third, the lower portions of the middle of a relatively deep deposit. The order of statement, when samples not average in their nature were taken, is from above downwards, i. e. T. M. B. Whenever appreciable differences were noted in the character of the deposit at different depths, samples were taken accordingly wherever feasible.

The caption covering the sub-captions over columns 7-12 reading "Composition of Dry Matter." Peat and muck are notoriously water-holding materials. Obviously their percentage composition is affected by their greater or less moisture contents. Accurate comparisons cannot be made unless the varied water contents of the several samples are taken into account and all are placed on a uniform basis. The basis uniformly chosen in such cases is that of absolute dryness. Hence the data here reported are all calculated from the figures attained in analyses to a condition of absolute freedom from water.

7. *Organic and volatile matter.* This figure shows the proportion of the entire dry sample which is capable of volatilization by heat. While perhaps some of the ash constituents—some of the potash for example—may be thus lost and, indeed, some escape mechanically despite the utmost care, on the other hand the ash is not pure, being in part carbonated from the organic matter while in process of combustion. The figure is, however, a fairly close measure of the organic matter resident in the dry matter of the sample under survey.

8. *Ash.* Crude ash, the residue left after the combustion, the mineral matter. When low, the organic matter naturally runs high, and vice versa. A high ash content usually de-

notes considerable soil admixture; a low ash content, a pure, uncontaminated product. Thus No. 132 on page 204 carries a high ash content—over 50 percent—and, doubtless, contains much soil, while No. 143 on the same page contains but a small amount of ash and, consequently, is a much higher grade both for fuel and for fertilizing purposes. The ash or mineral matter does not as a rule contain much plant food, although more or less lime, phosphoric acid and potash occur. (See in this connection page 174).

9. *Carbon* is well known to be the element which when oxydized (burned) evolves heat. A coal or wood fire, a burning kerosene lamp, a gas jet, give off heat because the carbon is being burned and changed to carbon dioxid (carbonic acid gas). Our bodies are kept warm by the same agency in the same manner. Hence the carbon content of a peat gives some indication of its value as fuel. Thus No. 132 on page 204 as compared with No. 141 on the same page carries less than half as much carbon and doubtless has at least no more than half its value as a heat producer.

10. *Hydrogen* is an element which is present in all organic matter. It is very light in weight. When combined with oxygen it form water; when combined with oxygen and carbon it forms multitudinous organic substances. It does not occur in peat and muck in any large quantites and averages but a little over 4 percent.

11. *Oxygen* is the life-giving element which, when combined with carbon, oxydizes it to carbon dioxid. Together with the carbon it constitutes three-fourths of the dry matter of the average peat and muck. As stated in the tabular matter the figures are obtained by difference, i. e., the other ingredients are determined directly and the differences between their sum and 100 is assumed to be oxygen and sulphur. The sulphur was not determined, but was lumped in with the oxygen. Peats and mucks usually carry a fraction of a percent of sulphur. A

few determinations made in the present study showed very small figures.

12. *Nitrogen* is a deficient and costly element of plant food. It is the main ingredient which, chemically, makes peat and muck worth using. Though relatively inert as compared with the nitrogen found in the better forms of fertilizer crude stock, more or less of it becomes available in time and serves to sustain plant growth.

The organic and volatile matter, ash, carbon, hydrogen, oxygen, and nitrogen figures just defined, show the percentages of these sundry materials and elements on a water-free basis, or in other words, on a dry matter basis.

Columns 13 to 15 as well as 19 are expressions of ratios.

13. The first column shows *the ratio of the carbon (9) to the sum of the ash (8) and oxygen (11)*. It is obtained by dividing the combined percentages of oxygen and ash by the carbon percentages of oxygen and ash by the incmfwypncmfnpn bon percentage. The oxygen content of a material which is capable of combustion lowers its fuel value about as seriously as does its ash content. This ratio affords a fairly accurate means of sorting samples of coals and peats as to their fuel efficiencies. Thus the more oxygen and ash percent in proportion to the carbon the larger the second term of the ratio expressed in the column; and vice versa. Thus No. 132 on page 204 shows a high ratio 1:3.1 and No. 144 a low ratio 1:0.8. The one has low, the other high, fuel efficiency.

14. *The relative efficiencies of peats as compared with coals* having a high percentage of carbon and high fuel values are shown by the data in this column. They are obtained by dividing the percentage of carbon (9) into the constant, 100, and multiplying the quotient by 100 in order to eliminate decimals. It is obvious that coal carrying 85 to 90 percent of carbon affords a figure approximating, say, 110, and that as the carbon percentage decreases this ratio increases. These figures then afford a means of sorting the various samples as to fuel efficiency in comparison with a substance approximating a 100 percent



PLATE XIII.—A pond artificially made by the excavation of peat on a farm in Marshfield, Washington county. (See pages 194, 214-215, 232).



PLATE XIV.—Drainage ditch in a large area of peat land in Westminster, Windham county. (See pages 195, 216-217, 233).



**PLATE XV.—Drainage ditch in a Franklin, Franklin county, deposit
(See pages 159, 186).**

carbon content, to which anthracite coal is the nearest approach among solid fuels. Thus No. 132 on page 204 with 433 as the product of this calculation, compares but poorly as to fuel value with Nos. 141 to 147 on the same page, which similarly calculated give figures ranging from 193 to 232.

15. The *ratio of hydrogen (10) to carbon (9)* is obtained by dividing the percentages of hydrogen into the corresponding carbon percentages. These values are designed especially to show the stage of decomposition to which any given material has arrived. Theoretically a high figure shows a greater and a low figure a lesser stage of decomposition. The ratio of hydrogen to carbon in anthracite coals runs as high as 33. The figures thus obtained are relatively unimportant in this connection.

16 and 17. "*Calories*" is a term referring to the theoretical heat units as calculated by the use of Mahler's formula.¹ The results stated in terms of calories may be converted into British thermal units by multiplying by 9/5. The calorie, or French thermal unit, is that quantity of heat which is required to raise the temperature of one kilogram of pure water 1° C when at or about 4° C (39.1° F.); or, approximately, 1 pound of water 4° F. Obviously the higher the figure, the greater the heat producing value of the sample, for the more pounds of water may be raised 4° F. by a unit of the material. Thus No. 132 on page

¹ Fuel values. A calorimeter being unavailable for this work, recourse was had to computations of the fuel values, applying sundry formulas to the figures obtained by ultimate analysis. Dulong's formula:

$$8000 C + 34500 (H - \frac{1}{8} O)$$

heating value equals $\frac{\quad}{100}$ was suggested;

but when applied to peat analyses it was found that in several cases one-eighth of the oxygen was a larger figure than was the hydrogen percentage itself. The samples displaying this situation were almost invariably sphagnum mosses or peats which, when sampled, were either completely submerged or in a thoroughly saturated condition. It was then decided to try Mahler's formula:

$$8140 C + 34500 [H - 3000 (O + N)].$$

heating value equals $\frac{\quad}{100}$

The author of this formula claims that it gives results within 3 percent of those afforded by direct calorimeter determination. These formulas state the calculated heating value in terms of calories.

204 with its 2103 calories, compares poorly with No. 142 on the same page which calculates 4985 calories. This poor showing, however, is mostly due to its high ash content. When this is eliminated the calorie figure jumps to 4306. The calculation on an ash free basis is mainly serviceable in that it gives some clue as to decomposition as described in the next paragraph.

18. The statement of the "*carbon content on an ash free basis*" is obtained by dividing the carbon percentage (9) on a water-free basis, by 100 minus the corresponding ash percentage (8). Theoretically, the carbon contents of the several samples representing different layers of a deposit, if these are all equally decomposed, and if their ash contents are determined correctly, should, when reduced to this ash free basis, be closely identical. Assuming that the method of determining the ash contents of peats gives fairly accurate results, any noticeable difference in a series of ash-free carbons would tend to show retarded decomposition when results are low, and advanced decomposition when they are high. Some of the layers contained more carbon in proportion to the ash present than did others; and some were found to be nearer the stage of coal formation than were others, the gaseous constituents being more thoroughly liberated and expelled and the carbon concentrated and retained. It is to be expected that the material derived from the deeper layers would show much more carbon on an ash-free basis than that occurring near the surface.

19. The "*ratio of nitrogen (12) to organic and volatile (combustible) matter (7)*" is obtained by dividing the percentages of nitrogen (12) into the organic and volatile matter percentage (7). This figure should aid in sorting peats and mucks as to their service in fertilization. Some such materials would be well worth using under some circumstances; others under other circumstances; and others not at all. The lower the figure the higher the nitrogen content and the better the sample for agricultural purposes. The results simply show in how many parts of organic matter is contained one part of nitrogen. It is

manifestly better in cases where nitrogen is the primal need to have a pound of nitrogen distributed among relatively few pounds of organic matter than among many. Samples showing low ash and low nitrogen percentages afford inevitably high ratios of nitrogen to organic and combustible matter. Such deposits might prove serviceable as a source of humus but not of nitrogen. Samples containing medium or high percentages of nitrogen and also of ash would display low ratios, for the reason that their small organic matter contents would show up proportionally high in comparison with nitrogen percentages. Samples of this type would represent materials particularly applicable to soils needing some humus but relatively more nitrogen. These points may be made the more clear if a concrete case is taken. Thus No. 142 and Nos. 145 to 147 on page 204 may be compared. The ratio figure in one case is 23, in the other 43. No. 142 is far the best of the lot; its low ratio figure shows this at a glance.

ANALYTICAL METHODS

Gross drying. In the regular station fodder sample dryer—a modified, gas-heated fruit evaporator, cubical contents approximately 150 cubic feet; dried for 3 days to a low moisture content at temperatures ranging from 120°-150° F., air dried by exposure, and ground for analysis.

Moisture in air dried sample. Air bath at 101° C. for 24 hours.

Nitrogen. Kjeldahl or Gunning.

Carbon. Combustion in an 18-burner combustion furnace, using 27.5 inch Jena tubing 11/16 inch exterior diameter; collection as CO₂ in KOH solution in Geissler bulbs with soda-lime U tube adjunct.

Hydrogen. Combustion in combustion furnace, collection as H₂O in CaCl₂ tube; correction made for the hydrogen of the water content as analyzed.

Ash. Residue from combustion determination of carbon and hydrogen.

Oxygen and sulphur. By difference.

ANALYSES OF VERMONT PEATS AND MUCKS

Sample number	Owner or occupant (1904-1907)	Nature or location of deposit	Area in acres	Depth in feet	Location of sample	COMPO- Organic and vola- tile matter, %
ADDISON COUNTY						
<i>Bridport</i>						
132	R. L. Heminway		150	3	A	48.81
133	J. W. Pratt, swale meadow.....			3	A	69.71
134	Ditto, alder meadow			3	A	65.06
<i>Bristol</i>						
141	Bristol pond area, edge of swamp.....				A	38.37
142	Ditto, from pond proper.....				A	83.08
143	Ditto, back from pond				A	95.29
144	Ditto, interior of swamp.....				A	92.65
145	Ditto, from cedar belt				T	87.25
146	Ditto, Ditto,				M	87.06
147	Ditto, Ditto,				B	90.09
<i>Monkton</i>						
139	A. N. Baldwin, at edge		50	5	A	87.39
140	Ditto, interior		50	5	A	76.52
138	Clark area, from wooded portion.....				A	93.78
<i>Shoreham</i>						
129	Shoreham swamp, from submerged area....			*	A	87.63
130	Ditto, drier part near center....				A	86.51
131	Ditto, swale belt				A	69.14
<i>Vergennes</i>						
148	Booth estate, very deep deposit.....				T	90.69
149	Ditto, Ditto,				B	88.92
Average for 18 samples						82.66
BENNINGTON COUNTY						
<i>Bennington</i>						
151	Bald mountain, sphagnum bog moss.....				T*	94.35
152	Ditto, surface peat				T	75.67
153	Ditto, bottom peat				B	84.31
121	R. O. Gove, 3 feet deep—very deep deposit...				A	63.28
150	Aaron Hill				A	46.98
122	Frank Rice, surface black				T	70.62
123	Ditto, underlying red brown strata				B	89.40
161	John Rockwood, black muck		4		T	60.08
162	Ditto, brown				B	60.88
201	Eugene West, black muck		5	4	T	82.75
202	Ditto, brownish; 1 foot thick...				B	81.89

*One mile square.

THE PEAT AND MUCK DEPOSITS OF VERMONT
ANALYSES OF VERMONT PEATS AND MUCKS

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POSITION OF DRY MATTER					FUEL VAL. RATIOS			FUEL VALUES			
Crude ash, %	Carbon, %	Hydrogen, %	Oxygen and sulphur, %	Nitrogen, %	Carbon to oxygen and ash, 1 :	Carbon $\times 100$, 1 :	Hydrogen to carbon, 1 :	Calories (calculated)	Calories (calculated) [on an ash free basis]	Carbon content [on an ash free basis]	Nitrogen to organic & volatile matter, 1 :
ADDISON COUNTY											
<i>Bridport</i>											
51.19	23.13	2.64	21.05	1.99	3.1	433	8.8	2103	4306	47.39	25
30.29	38.00	3.40	25.62	2.69	1.5	263	11.2	3417	4902	54.51	26
34.94	35.51	4.03	23.26	2.26	1.7	282	8.8	2982	4580	54.58	29
<i>Bristol</i>											
11.63	49.62	3.85	32.51	2.39	0.9	202	12.9	4320	4889	56.14	37
16.92	43.16	7.12	29.23	3.57	1.0	232	6.1	4985	6000	51.95	23
4.71	45.67	4.40	42.34	2.88	1.0	219	10.4	3879	4071	47.93	33
7.35	51.82	3.82	34.39	2.62	0.8	193	13.6	4426	4778	55.93	35
12.75	48.15	3.30	33.78	2.02	1.0	208	14.6	3984	4566	55.19	43
12.94	48.77	4.07	32.20	2.02	0.9	205	12.0	4347	4993	56.02	43
9.91	49.27	3.45	35.27	2.10	0.9	203	14.3	4080	4529	54.69	43
<i>Monkton</i>											
12.61	46.40	4.08	34.48	2.43	1.0	216	11.4	4078	4667	53.10	36
23.48	43.40	4.12	26.72	2.28	1.2	230	10.5	4084	5338	56.72	34
6.22	51.03	4.53	36.03	2.19	0.8	196	11.3	4570	4873	54.41	43
<i>Shoreham</i>											
12.37	47.05	4.74	32.68	3.16	1.0	213	10.0	4390	5010	53.69	28
13.49	45.31	4.43	33.48	3.29	1.0	221	10.2	4113	4755	52.37	26
30.86	38.84	3.34	24.93	2.03	1.4	257	11.6	3510	5075	56.18	34
<i>Vergennes</i>											
9.31	51.29	4.39	31.93	3.08	0.8	195	11.7	4639	5116	56.56	29
11.08	49.98	3.86	32.37	2.71	0.9	200	13.0	4349	4891	56.21	33
17.34	44.80	4.23	31.39	2.54	1.1	223	11.2	4045	4894	54.20	33
BENNINGTON COUNTY											
<i>Bennington</i>											
5.65	47.78	5.40	39.90	1.27	1.0	209	8.9	4517	4788	50.64	74
24.33	43.54	2.83	27.79	1.51	1.2	230	15.4	3641	4812	57.54	50
15.69	48.06	4.01	30.57	1.67	1.0	208	12.0	4328	5134	57.00	51
36.72	35.10	2.37	23.78	2.03	1.7	285	14.8	2901	4585	55.47	31
53.02	24.30	2.54	18.46	1.68	2.9	412	9.6	2250	4790	51.72	28
29.38	35.68	3.60	28.85	2.49	1.6	280	9.9	3207	4541	50.52	28
10.60	49.76	4.82	32.31	2.51	0.9	201	10.3	4669	5222	55.56	36
39.92	34.13	3.44	20.28	2.23	1.8	293	9.9	3290	5476	56.81	27
39.12	30.50	2.62	26.14	1.62	2.2	328	11.7	2554	4195	50.10	38
17.25	46.93	3.80	29.85	2.17	1.0	213	12.4	4171	5041	56.72	38
18.11	44.61	3.74	31.92	1.62	1.1	224	11.9	3915	4781	54.48	51

ANALYSES OF VERMONT PEATS AND MUCKS—*Continued*

Sample number	Owner or occupant (1904-1907)	Nature or location of deposit	Area in acres	Depth in feet	Location of sample	COMPO- Organic and vola- tile matter, %
BENNINGTON COUNTY—(continued)						
<i>Manchester</i>						
118	F. D. Giddings, contains many pebbles.....		4	3	A	43.86
127	Thompson, from meadow land.....				T	86.25
128	Ditto, contains much decayed wood				B	89.64
<i>South Shaftsbury</i>						
266	Peleg Cole estate, red brown; near swamp edge			very 7 deep	T	88.20
267	Ditto, Ditto,				M	88.43
268	Ditto, Ditto,				M	79.70
269	Ditto, from interior				A	88.85
<i>Sunderland</i>						
126	Jerome Hill, "Sink Hole"		1		A	95.04
	Average of 19 samples.....					77.38
CHITTENDEN COUNTY						
<i>Charlotte</i>						
296	Miss G. Horsford, cranberry bog.....		25	2	T	76.91
297	Ditto, Ditto,				B	60.33
298	Ditto, Ditto,				T	73.34
299	Ditto, Ditto,				M	84.60
300	Ditto, Ditto,				B	63.27
<i>Colchester</i>						
207	Barstow estate at Colchester Point.....			very deep	T	94.18
208	Ditto, Ditto,				B	94.07
<i>Jericho</i>						
213	Jordan Bros., meadow bog; black.....		6	12	T	86.84
214	Ditto, Ditto,		6	12	M	87.86
215	Ditto, Ditto,				B	90.09
216	B. H. Stone, cranberry swamp, top layer of moss				A	96.44
217	Ditto, near edge of clearing.....				A	96.51
218	Ditto, from wooded portion				A	91.88
<i>South Burlington</i>						
64	L. A. & A. A. Drew estate, southeast corner..		100	5	T	74.57
65	Ditto, Ditto,				B	72.98
66	Ditto, northeast corner				A	44.72
70	Ditto, east border				A	71.20
67	Ditto, northwest corner		100	5	T	95.91
68	Ditto, Ditto,				M	96.84
69	Ditto, Ditto,				B	94.97
71	Ditto, clearing southwest corner				T	96.96

ANALYSES OF VERMONT PEATS AND MUCKS—*Continued*

-SITION OF DRY MATTER					FUEL VAL. RATIOS				FUEL VALUES			
Crude ash, %	Carbon, %	Hydrogen, %	Oxygen and sulphur, %	Nitrogen, %	Carbon to oxygen and ash, 1:	Carbon $\times 100$, 1:	Hydrogen to carbon, 1:	Calories (calculated)	Calories (calculated) [on an ash free basis]	Carbon content [on an ash free basis]	Nitrogen to organic & volatile matter, 1:	
BENNINGTON COUNTY—(continued)												
<i>Manchester</i>												
56.14	25.20	2.75	14.33	1.58	2.8	397	9.2	2523	5753	57.46	28	
13.75	46.15	3.78	32.52	3.80	1.0	217	12.2	3991	4627	53.51	23	
10.36	42.50	5.68	38.69	2.77	1.2	236	7.5	4175	4658	47.54	32	
<i>South Shaftsbury</i>												
11.80	47.74	4.44	33.09	2.93	0.9	209	10.8	4337	4917	54.13	30	
11.57	48.64	4.50	32.10	3.19	0.9	206	10.8	4452	5035	55.00	28	
20.30	44.63	3.78	28.85	2.44	1.1	224	11.8	3998	5017	55.99	33	
11.15	49.88	4.76	31.55	2.66	0.9	200	10.5	4676	5263	56.14	33	
<i>Sunderland</i>												
4.96	47.87	5.17	40.77	1.23	1.0	209	9.3	4421	4652	50.37	77	
22.62	41.74	3.89	29.57	2.18	1.3	240	10.7	3787	4892	53.95	36	
CHITTENDEN COUNTY												
<i>Charlotte</i>												
23.09	39.39	3.27	31.27	2.98	1.4	254	12.1	3306	4299	51.21	26	
39.67	30.62	3.18	24.21	2.32	2.1	327	9.6	2793	4630	50.76	26	
26.66	34.65	2.78	32.95	2.96	1.7	289	12.5	2704	3687	47.25	25	
15.40	42.01	3.02	36.31	3.26	1.2	238	13.9	3275	3872	49.66	26	
36.73	28.97	2.51	29.72	2.07	2.3	345	11.5	2269	3587	45.79	31	
<i>Colchester</i>												
5.82	52.80	5.21	33.20	2.97	0.7	189	10.1	5009	5335	56.07	32	
5.93	52.99	4.81	33.33	2.94	0.7	189	11.0	4884	5188	56.33	32	
<i>Jericho</i>												
13.16	44.55	4.18	35.47	2.64	1.1	224	10.7	3926	4521	51.30	33	
12.14	48.81	4.06	32.68	2.31	0.9	205	12.0	4324	4922	55.55	38	
9.91	50.03	4.21	32.86	2.99	0.9	200	11.9	4449	4939	55.54	30	
3.56	49.52	5.45	39.89	1.58	0.9	202	9.1	4667	4840	51.35	61	
3.49	50.69	4.41	39.56	1.85	0.8	197	11.5	4405	4565	52.52	52	
8.12	50.12	4.31	35.03	2.42	0.9	200	11.6	4443	4836	54.55	38	
<i>South Burlington</i>												
25.43	41.43	3.46	28.01	1.67	1.3	241	12.0	3677	4931	55.56	45	
27.02	44.95	4.50	22.31	1.22	1.1	222	10.0	4506	6175	61.59	60	
55.28	33.23	3.32	16.98	1.19	3.1	431	7.0	2492	5573	51.95	38	
28.80	41.64	4.12	24.06	1.38	1.3	240	10.1	4048	5686	58.48	52	
4.09	47.91	4.69	41.97	1.34	1.0	209	10.2	4219	4399	49.95	72	
3.16	58.32	6.48	29.17	2.87	0.6	171	9.0	6024	6221	60.23	34	
5.03	58.95	4.55	30.62	0.85	0.6	170	13.0	5425	5713	62.07	112	
3.04	48.24	6.05	41.73	0.94	0.9	207	8.0	4733	4882	49.75	103	

ANALYSES OF VERMONT PEATS AND MUCKS—*Continued*

Sample number	Owner or occupant (1904-1907)	Nature or location of deposit	Area in acres	Depth in feet	Location of sample	COMPO- sition Organic and vola- tile matter, %
CHITTENDEN COUNTY—(continued)						
<i>South Burlington</i> —(continued)						
72	L. A. & A. A. Drew estate, clearing southwest cor.				M	97.33
73	Ditto,	Ditto,			B	95.48
76	Ditto,	Ditto,			T	95.17
75	Ditto,	Ditto,			M	94.04
74	Ditto,	Ditto,			M	93.08
82	Ditto,	deep down			A	96.01
77	Ditto,	below moss	100	5	T	96.75
78	Ditto,	near southwest corner...			M	96.23
79	Ditto,	Ditto,			M	93.52
80	Ditto,	Ditto,			B	52.94
<i>Westford</i>						
209	L. C. Nichols, meadow basin; black.....		20	10	T	74.15
210	Ditto,	Ditto; brown			M	34.29
211	Ditto,	Ditto,			M	89.53
212	Ditto,	Ditto; brown gray			B	33.84
Average of 35 samples						82.48
FRANKLIN COUNTY						
<i>Franklin</i>						
155	Cranberry marsh		200	30+	T	96.46
154	Ditto,				M	97.39
156	Ditto,				A	94.89
157	J. W. Grant, Willard farms		50	6	T	88.41
158	Ditto,				B	84.05
<i>Highgate</i>						
230	Jewett farm		50	deep	T	95.09
231	Ditto,				M	92.82
232	Ditto,				M	93.81
233	Ditto,				M	93.50
234	Ditto,				M	92.65
<i>Richford</i>						
235	Moses Pattee & Sons, middle of area.....		40	15	T	63.64
236	Ditto,				M	87.62
237	Ditto,				B	88.81
238	Ditto,				M	88.60
239	Ditto,	wooded section			M	89.18
240	Ditto,				M	96.38
Average of 16 samples						90.21

ANALYSES OF VERMONT PEATS AND MUCKS—*Continued*

POSITION OF DRY MATTER					FUEL VAL. RATIOS			FUEL VALUES			
Crude ash, %	Carbon, %	Hydrogen, %	Oxygen and sulphur, %	Nitrogen, %	Carbon to oxygen and ash, 1:	Carbon $\times 100$, 1: 100	Hydrogen to carbon, 1:	Calories (calculated)	Calories (calculated) [on an ash free basis]	Carbon content [on an ash free basis]	Nitrogen to organic & volatile matter, 1:
CHITTENDEN COUNTY—(continued)											
<i>South Burlington—(continued)</i>											
2.67	55.05	5.28	35.51	1.49	0.7	182	10.4	5190	5333	56.56	65
4.52	58.57	5.70	30.26	0.95	0.6	171	10.3	5799	6074	61.34	101
4.83	47.28	4.67	41.96	1.26	1.0	212	10.1	4163	4375	49.68	76
5.96	54.45	5.34	32.64	1.61	0.7	184	10.2	5249	5582	58.01	58
6.92	58.84	5.41	27.74	1.09	0.6	170	10.9	5791	6222	63.22	85
3.99	57.80	6.05	31.36	0.80	0.6	173	9.6	5327	6070	60.20	120
3.22	57.46	5.73	32.53	1.06	0.6	174	10.0	5647	5835	59.37	91
3.77	59.60	5.47	30.17	0.99	0.6	168	10.9	5804	6032	61.94	97
6.48	55.70	4.89	31.20	1.73	0.7	180	11.4	5233	5596	59.56	54
47.06	27.51	2.67	20.69	2.07	2.4	364	10.3	2577	4865	51.93	26
<i>Westford</i>											
25.85	38.53	3.26	29.61	2.75	1.4	260	11.8	3290	4437	51.96	27
65.71	18.04	1.78	13.39	1.08	4.4	554	10.1	1648	4807	52.61	32
10.47	49.43	3.69	34.81	1.60	0.9	202	13.4	4205	4697	55.21	56
66.16	18.83	2.05	11.55	1.41	4.1	531	9.2	1850	5467	55.65	24
17.52	45.63	4.30	30.70	1.85	1.1	219	10.6	4222	5120	55.33	45
FRANKLIN COUNTY											
<i>Franklin</i>											
3.54	49.06	4.86	41.34	1.20	0.9	204	10.1	4394	4556	50.86	80
2.61	50.72	5.18	40.49	1.00	0.9	197	9.8	4671	4797	52.08	97
5.11	51.14	4.60	37.65	1.50	0.8	196	11.1	4576	4823	53.90	63
11.59	51.93	4.92	29.46	2.10	0.8	193	10.6	4977	5629	58.74	42
15.95	40.97	5.05	35.42	2.61	1.3	244	8.1	3936	4683	48.74	32
<i>Highgate</i>											
4.91	53.31	4.75	35.55	1.48	0.9	188	11.2	4868	5119	56.07	58
7.18	50.25	4.53	36.20	1.84	0.9	199	11.1	4512	4861	54.14	50
6.19	42.86	4.22	44.86	1.87	1.2	233	10.2	3543	3777	45.69	50
6.50	57.82	5.61	28.41	1.66	0.6	173	10.3	5739	6138	61.84	56
7.35	52.61	3.25	34.84	1.95	0.8	190	16.2	4300	4642	56.79	48
<i>Richford</i>											
36.36	31.80	3.23	26.90	1.71	2.0	314	9.8	2844	4469	49.97	37
12.38	51.34	4.68	29.30	2.30	0.8	195	11.0	4846	5531	58.60	38
11.19	50.53	4.33	31.35	2.60	0.8	198	11.7	4589	5167	56.90	34
11.40	46.95	3.75	35.43	2.47	1.0	213	12.5	3053	3446	52.99	36
10.82	51.35	4.12	31.44	2.27	0.8	195	12.5	4590	5145	57.58	39
3.62	52.64	3.97	38.19	1.58	0.8	190	13.3	4462	4630	54.62	61
9.79	49.09	4.44	34.80	1.88	0.9	204	11.4	4427	4908	54.40	48

ANALYSES OF VERMONT PEATS AND MUCKS—Continued

Sample number	Owner or occupant (1904-1907)	Nature or location of deposit	Area in acres	Depth in feet	Location of sample	COMPO- Organic and vola- tile matter, %
GRAND ISLE COUNTY						
<i>Alburg</i>						
52	Lyman swamp; extensive; near edge.....		6	10	A	85.14
54	Ditto,				T	82.01
53	Ditto,				B	87.17
55	Canadian line swamp; near edge; very deep.				A	68.93
56	Ditto, interior				A	91.29
50	Mott farm; cattail swamp				T	88.89
51	Ditto, Ditto,				B	87.22
<i>Grand Isle</i>						
17	A. H. Hyde; black muck over marl.....				A	75.60
15	Reynolds' cedar swamp; near edge.....			1½	A	77.97
16	Ditto, interior			2½	A	87.21
<i>Isle La Motte</i>						
59	H. H. Hill; turf peat, very thick.....				T	90.72
61	Ditto,				B	84.39
62	Ditto, middle of swamp, but little sod				M	90.25
63	Ditto, deeper layer				M	92.58
<i>North Hero</i>						
36	W. B. Dodds; alder swamp, wet area.....		100		A	92.12
37	Ditto,			6	T	92.00
38	Ditto,				B	89.83
39	Ditto, dryer area, under thick sod....				A	92.78
40	Ditto,				A	90.40
43	Allen's creek, interior of marsh.....		6	6	A	88.34
44	John Dubuc, near edge		20		A	89.71
46	Ditto, interior				T	87.01
45	Ditto,				B	90.45
49	Macomber, from wooded part				A	79.36
<i>South Hero</i>						
6	S. P. Gordon estate, Pearl swamp.....		100		A	94.48
7	Ditto,				T	95.02
8	Ditto,				B	94.05
11	Ditto,				T	97.03
10	Ditto,				B	89.62
12	Ditto,				A	92.81
24	Alson Landon; Round pond, silt-like material				A	79.12
25	Ditto, edge				A	86.43
28	Ditto, interior				T	85.70

THE PEAT AND MUCK DEPOSITS OF VERMONT 211
ANALYSES OF VERMONT PEATS AND MUCKS—*Continued*

POSITION OF DRY MATTER					FUEL VAL. RATIOS			FUEL VALUES				
Crude ash, %	Carbon, %	Hydrogen, %	Oxygen and sulphur, %	Nitrogen, %	Carbon to oxygen and ash, 1:	Carbon $\times 100$, 1:	Hydrogen to carbon, 1:	Calories (calculated)	Calories (calculated) [on an ash free basis]	Carbon content [on an ash free basis]	Nitrogen to organic & volatile matter, 1:	
GRAND ISLE COUNTY												
<i>Alburg</i>												
14.86	40.83	3.95	37.72	2.64	1.3	245	10.3	3477	4084	47.96	32	
17.99	40.39	3.19	36.47	1.96	1.3	248	12.7	3236	3946	49.25	42	
12.83	45.19	5.14	34.98	1.86	1.1	221	8.8	4347	4987	51.82	47	
31.07	34.78	3.21	28.79	2.15	1.7	288	10.8	3010	4367	50.46	32	
8.71	51.00	4.15	34.09	2.05	0.8	196	12.3	4500	4930	55.86	45	
11.11	42.78	4.86	37.95	3.30	1.1	234	8.8	3923	4412	48.13	27	
12.78	44.66	4.74	34.91	2.91	1.1	224	9.4	4135	4742	51.21	30	
<i>Grand Isle</i>												
24.40	44.78	3.70	24.55	2.57	1.1	223	12.1	4108	5434	59.24	29	
22.03	41.09	4.35	29.86	2.67	1.3	243	9.4	3870	4963	52.70	29	
12.79	45.54	4.60	34.11	2.96	1.0	220	9.9	4181	4794	52.21	30	
<i>Isle La Motte</i>												
9.28	46.94	4.68	35.48	3.62	1.0	213	10.0	4262	4698	51.74	25	
15.61	41.83	4.13	34.81	3.62	1.2	239	10.1	3676	4356	49.56	23	
9.75	44.60	5.78	35.68	4.19	1.0	224	7.7	4429	4908	49.42	22	
7.42	48.87	4.89	36.37	2.45	0.9	205	10.0	4500	4861	52.79	38	
<i>North Hero</i>												
7.88	45.31	4.80	38.63	3.38	1.0	221	9.4	4080	4434	49.19	27	
8.00	43.79	4.77	39.64	3.80	1.1	228	9.2	3908	4248	47.60	24	
10.17	46.20	5.17	35.33	3.13	1.0	216	8.9	4391	4888	51.44	29	
7.22	46.31	5.05	37.62	3.80	1.0	216	9.2	4269	4601	49.91	24	
9.60	44.62	4.83	37.46	3.49	1.1	224	9.2	4070	4503	49.36	26	
11.66	44.25	4.91	36.30	2.88	1.1	226	9.2	4121	4665	50.09	31	
10.29	44.84	5.23	36.57	3.07	1.0	223	8.6	4263	4752	49.98	29	
12.99	39.74	4.65	39.85	2.77	1.3	252	8.5	3559	4091	45.68	31	
9.55	45.99	4.51	36.47	3.48	1.0	217	10.2	4102	4535	50.85	26	
20.64	41.34	3.53	31.78	2.71	1.3	242	11.7	3548	4471	52.09	29	
<i>South Hero</i>												
5.52	59.13	5.20	28.98	1.17	0.6	169	11.4	5702	6036	62.59	81	
4.98	54.45	4.96	33.76	1.85	0.7	184	11.0	5075	5341	57.30	51	
5.95	57.94	5.05	30.07	0.99	0.6	173	11.5	5526	5876	61.60	95	
2.97	52.94	4.84	37.68	1.57	0.8	189	10.9	4803	4949	54.56	62	
10.38	53.00	4.02	30.98	1.62	0.8	189	13.2	4723	5270	59.14	55	
7.19	54.95	5.54	30.88	1.44	0.7	182	9.9	5414	5833	59.21	64	
20.88	37.75	5.00	33.06	3.31	1.4	265	7.6	3707	4685	47.71	24	
13.57	41.66	4.44	37.70	2.63	1.2	240	9.4	3713	4296	48.20	33	
14.30	42.95	4.28	35.85	2.62	1.2	233	10.0	3818	4455	50.11	33	

ANALYSES OF VERMONT PEATS AND MUCKS—*Continued*

Sample number	Owner or occupant (1904-1907)	Nature or location of deposit	Area in acres	Depth in feet	Location of sample	COMPO
						Organic and vola- tile matter, %

GRAND ISLE COUNTY—(continued)

South Hero—(continued)

27	Alson Landon, Round pond, interior.....				M	87.08
26	Ditto,				M	88.81
29	Ditto,				B	90.29
31	Edward Phelps, small stump swamp; thin..				A	83.06
Average of 37 samples						87.70

LAMOILLE COUNTY

Johnson

219	B. A. Hunt, moss in clearing.....	100	7	T		97.97
220	Ditto, silt (?) in same.....				A	96.61
221	Ditto, edge of clearing.....				T	94.85
222	Ditto, timberland, top of deposit				T	91.26
223	Ditto, timberland, near bottom.				M	92.72
225	Ditto, Sterling pond; reddish peat.....				A	91.16
226	Edward Magoon, turf, muck and peat.....	8	6-12	T		70.29
227	Ditto,				M	78.64
228	Ditto,				M	77.00
229	Ditto,				B	46.72
Average of 10 samples						83.72

ORANGE COUNTY

Vershire

256	E. P. George estate, large swamp.....	shallow			A	81.74
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West Fairlee

253	Knight Bros., wild meadow	20	v'y d'p	A		71.13
254	Ditto,				T	91.42
255	Ditto,				B	94.31

Williamstown

101	Wm. C. Pratt, grassed area.....	30	v'y d'p	A		81.70
102	Ditto,				T	75.05
103	Ditto,				B	66.09
Average of 7 samples						80.21

ANALYSES OF VERMONT PEATS AND MUCKS—Continued

POSITION OF DRY MATTER					FUEL VAL. RATIOS			FUEL VALUES			
Crude ash, %	Carbon, %	Hydrogen, %	Oxygen and sulphur, %	Nitrogen, %	Carbon to oxygen and ash, 1:	Carbon $\times 100$, 1: 100	Hydrogen to carbon, 1:	Calories (calculated)	Calories (calculated) [on an ash free basis]	Carbon content [on an ash free basis]	Nitrogen to organic & volatile matter, 1:

GRAND ISLE COUNTY—(continued)

South Hero—(continued)

12.92	44.33	4.41	35.44	2.90	1.1	226	10.1	3980	4571	50.91	30
11.19	45.01	4.64	36.13	3.03	1.1	222	9.7	4090	4606	50.68	29
9.71	44.02	4.94	38.35	2.98	1.1	227	8.9	4047	4483	48.75	30
16.94	42.00	4.51	34.65	1.90	1.2	238	9.3	3879	4670	50.56	44
12.30	45.56	4.61	34.84	2.69	1.0	219	9.9	4173	4757	51.93	33

LAMOILLE COUNTY

Johnson

2.03	49.47	3.71	43.66	1.13	0.9	202	13.3	3963	4045	50.50	87
3.39	51.74	4.77	37.53	2.57	0.8	193	10.8	4654	4818	53.56	38
5.15	49.94	3.53	39.50	1.88	0.9	200	14.1	4069	4290	52.65	51
8.74	50.81	3.82	34.44	2.19	0.9	197	13.3	4355	4772	55.68	42
7.28	51.56	3.90	34.89	2.37	0.8	194	13.2	4424	4772	55.61	39
8.84	48.14	4.24	36.30	2.48	0.9	208	11.4	4218	4627	52.81	37
29.71	31.32	2.62	33.84	2.51	2.0	319	11.2	2363	3362	44.56	28
21.36	45.74	3.95	26.53	2.42	1.0	219	11.6	4218	5364	58.16	33
23.00	43.28	3.72	27.96	2.04	1.2	231	11.6	3906	5073	56.21	38
53.28	24.95	2.72	17.46	1.59	2.8	401	9.2	2397	5131	53.40	29
16.28	44.70	3.69	33.21	2.12	1.1	224	11.8	3852	4600	53.40	40

ORANGE COUNTY

Vershire

18.26	43.73	3.94	31.26	2.81	1.1	229	11.1	3897	4768	53.50	29
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West Fairlee

28.87	34.73	4.25	30.10	2.05	1.7	288	8.2	3328	4680	48.82	35
8.58	50.21	4.98	33.36	2.87	0.8	199	10.1	4718	5162	54.92	32
5.69	53.07	5.16	33.85	2.23	0.7	188	10.3	5018	5320	56.27	42

Williamstown

18.30	43.89	3.50	31.58	2.73	1.1	228	12.6	3752	4593	53.72	30
24.95	36.89	4.48	30.40	3.28	1.5	271	8.2	3539	4716	49.15	23
33.91	37.28	4.11	22.09	2.61	1.5	268	8.5	3712	5616	56.41	25
19.79	42.83	4.35	30.38	2.65	1.2	237	9.8	3994	4979	53.40	30

ANALYSES OF VERMONT PEATS AND MUCKS—*Continued*

Sample number	Owner or occupant (1904-1907)	Nature or location of deposit	Area in acres	Depth in feet	Location of sample	COMPO- Organic and vola- tile matter, %
ORLEANS COUNTY						
Albany						
248	Vance estate, wild overgrown swamp clearing	100			T	96.83
249	Ditto,				M	95.77
250	Ditto,				B	93.30
251	Ditto, wooded area				T	89.88
252	Ditto,				B	62.41
Glover						
241	Runaway pond area	50	1-40	A		76.62
Average of 6 samples						85.80
RUTLAND COUNTY						
Benson						
135	Strong Bros., sage brush bog, muck and marl	40			A	62.14
WASHINGTON COUNTY						
Marshfield						
106	G. L. Dwinell, beaver meadow.....	40	v'y d'p	T		91.29
107	Ditto,				B	72.83
108	J. A. Ennis, deep red brown peat.....	30			T	92.35
109	Ditto,				M	92.87
Average of 4 samples						87.33
WINDHAM COUNTY.						
Stratton						
271	H. P. Forrester, mud pond	10	4	A		70.26
272	A. J. Pike; Stratton pond, cranberry meadow				T	96.02
273	Ditto,	large			M	97.50
274	Ditto,				M	97.49
275	Ditto, reed meadow....	very deep			T	87.74
276	Ditto,				M	83.51
277	Ditto,				M	71.33
278	Ditto,				B	74.44
279	Ditto, huckleberry meadow				A	97.27

ANALYSES OF VERMONT PEATS AND MUCKS—*Continued*

POSITION OF DRY MATTER					FUEL VAL. RATIOS			FUEL VALUES			
Crude ash, %	Carbon, %	Hydrogen, %	Oxygen and sulphur, %	Nitrogen, %	Carbon to oxygen and ash, 1:	Carbon $\times 100$, 1: 100	Hydrogen to carbon, 1:	Calories (calculated)	Calories (calculated) [on an ash free basis]	Carbon content [on an ash free basis]	Nitrogen to organic & volatile matter, 1:
ORLEANS COUNTY											
<i>Albany</i>											
3.17	55.18	4.71	35.06	1.88	0.7	181	11.7	5009	5174	56.99	52
4.23	56.77	4.95	32.75	1.30	0.7	176	11.5	5308	5543	59.28	74
6.70	54.14	4.08	32.63	2.45	0.7	185	13.3	4763	5105	58.03	38
10.12	42.03	4.85	40.10	2.90	1.2	238	8.7	3804	4233	46.76	31
37.59	31.69	3.74	24.56	2.42	2.0	316	8.5	3061	4905	50.78	26
<i>Glover</i>											
23.38	40.97	3.49	29.03	3.13	1.3	244	11.7	3574	4665	53.47	25
14.20	46.80	4.30	32.36	2.34	1.0	214	10.9	4253	4958	54.53	37
RUTLAND COUNTY											
<i>Benson</i>											
37.86	34.39	3.21	22.43	2.11	1.8	291	10.7	3171	5103	55.34	29
WASHINGTON COUNTY											
<i>Marshfield</i>											
8.71	48.25	5.36	34.52	3.16	0.9	207	9.0	4646	5089	52.85	29
27.17	41.05	3.84	25.52	2.42	1.3	244	10.7	3827	5265	56.36	30
7.65	50.01	4.81	34.65	2.88	0.8	200	10.4	4604	4985	54.15	32
7.13	51.28	5.56	33.92	2.11	0.8	195	9.2	5011	5396	55.21	44
12.67	47.65	4.89	32.15	2.64	0.9	210	9.7	4521	5179	54.53	33
WINDHAM COUNTY.											
<i>Stratton</i>											
29.74	37.43	3.69	27.01	2.13	1.5	267	10.1	3446	4905	53.27	33
3.98	48.50	6.13	40.35	1.04	0.9	206	7.9	4821	5021	50.51	92
2.50	52.14	5.38	38.47	1.51	0.8	192	9.7	4900	5026	53.48	65
2.51	52.35	5.04	38.51	1.59	0.8	191	10.4	4798	4922	53.70	61
12.26	46.16	3.43	35.33	2.82	1.0	217	13.5	3796	4327	52.61	31
16.49	46.40	4.78	29.74	2.59	1.0	216	9.7	4456	5336	55.56	32
28.67	40.92	3.95	24.35	2.11	1.3	244	10.4	3900	5468	57.37	34
25.56	43.70	2.75	26.17	1.82	1.2	229	15.9	3666	4925	58.70	41
2.73	56.42	4.78	34.34	1.73	0.7	177	11.8	5160	5305	58.00	56

ANALYSES OF VERMONT PEATS AND MUCKS—*Continued*

Sample number	Owner or occupant (1904-1907)	Nature or location of deposit	Area in acres	Depth in feet	Location of sample	Organic and volatile matter, %
WINDHAM COUNTY—(continued)						
Westminster						
280	David Taylor, upper end of bog.....	50 v'y d'p	T			62.27
281	Ditto,		M			55.56
282	Ditto,		M			54.02
283	Ditto,		M			63.05
284	Ditto,		M			43.97
285	Ditto, clay layer		M			22.04
286	Ditto, center of bog		B			62.48
287	Ditto,		M			71.78
288	Ditto,		B			34.18
Average of 18 samples.....						69.16
WINDSOR COUNTY						
Chester						
289	J. A. Chandler	50 v'y d'p	T			28.66
290	Ditto,		M			89.11
291	Ditto,		M			72.52
292	Ditto,		B			54.36
293	I. Clark		T			93.69
294	Ditto,		M			94.10
295	Ditto,		B			88.74
Ludlow						
160	L. W. Barton, moss	2	G	T		97.82
115	Ditto, sphagnum bog			T		97.76
116	Ditto,			M		98.57
117	Ditto,			M		97.79
Woodstock						
159	Billings farm, from large pond.....			A		95.15
Average of 12 samples						84.03

ANALYSES OF VERMONT PEATS AND MUCKS—*Continued*

-SITION OF DRY MATTER					FUEL VAL. RATIOS			FUEL VALUES			
Crude ash, %	Carbon, %	Hydrogen, %	Oxygen and sulphur, %	Nitrogen, %	Carbon to oxygen and ash, 1:	Carbon $\times 100$, 1: 100	Hydrogen to carbon, 1:	Calories (calculated)	Calories (calculated) [on an ash free basis]	Carbon content [on an ash free basis]	Nitrogen to organic & volatile matter, 1:
WINDHAM COUNTY—(continued)											
<i>Westminster</i>											
37.73	34.96	3.22	21.75	2.34	1.7	286	10.9	3234	5194	56.14	27
44.44	30.11	2.99	20.45	2.01	2.2	332	10.1	2809	5056	54.20	28
45.98	29.02	3.05	19.99	1.96	2.3	345	9.5	2755	5100	53.72	28
36.95	32.47	3.41	24.90	2.27	1.9	308	9.5	3004	4765	51.50	28
56.03	24.32	2.44	15.80	1.41	3.0	411	10.0	2306	5244	55.31	31
77.96	12.70	1.30	7.24	0.80	6.7	787	9.8	1242	5636	57.63	28
37.52	33.92	2.89	23.58	2.09	1.8	295	11.7	2988	4783	54.29	30
28.22	39.15	3.74	26.31	2.58	1.4	255	10.5	3610	5030	54.54	28
65.82	18.33	1.96	12.35	1.54	4.3	546	9.4	1751	5124	53.63	22
30.84	37.72	3.61	25.92	1.91	1.5	265	10.4	3480	5034	54.54	36
WINDSOR COUNTY											
<i>Chester</i>											
71.34	13.90	1.68	11.85	1.23	6.0	719	8.3	1319	4603	48.50	23
10.89	49.93	4.89	32.08	2.21	0.9	200	10.2	4722	5299	56.03	40
27.48	41.06	3.98	25.15	2.33	1.3	244	10.3	3891	5366	56.62	31
45.64	29.89	3.42	19.49	1.56	2.2	334	8.7	2981	5484	54.99	35
6.31	53.58	4.40	33.25	2.46	0.7	187	12.2	4809	5133	57.19	38
5.90	53.36	4.66	33.68	2.40	0.7	187	11.5	4869	5174	56.71	39
11.26	50.12	3.94	32.55	2.13	0.9	200	12.7	4399	4957	56.48	42
<i>Ludlow</i>											
2.18	49.85	5.32	40.65	2.00	0.9	201	9.4	4614	4716	50.96	49
2.24	53.35	5.76	36.55	2.10	0.7	187	9.3	5171	5290	54.57	47
1.43	57.71	5.69	33.52	1.65	0.6	173	10.1	5606	5688	58.55	60
2.21	53.66	6.06	36.53	1.54	0.7	186	8.8	5317	5436	54.87	64
<i>Woodstock</i>											
4.85	49.85	4.85	38.29	2.16	0.9	201	10.3	4518	4748	52.39	44
15.97	46.36	4.55	31.14	1.98	1.0	216	10.2	4349	5167	55.17	42

SUMMARY BY COUNTIES (ALL SAMPLES)

Sample number	COMPOSITION OF DRY MATTER					FUEL VAL. RATIOS			FUEL VALUES				
	Organic and volatile matter, %	Crude ash, %	Carbon, %	Hydrogen, %	Oxygen and sulphur, %	Nitrogen, %	Carbon to oxygen and ash, 1 :	Carbon $\times 100$, 1 :	Hydrogen to carbon, 1 :	Calories (calculated)	Calories (calculated) (on ash free basis)	Carbon content (on ash free basis)	Nitrogen to organic & volatile matter, 1 :
18 Addison	62.66	17.34	44.80	4.09	31.23	2.54	1.1	223	11.2	4045	4894	54.20	33
19 Bennington	77.38	22.62	41.74	3.89	29.57	2.18	1.3	240	10.7	3787	4892	53.95	36
35 Chittenden	82.48	17.52	45.63	4.30	30.70	1.85	1.1	219	10.6	4222	5120	55.33	45
16 Franklin	90.21	9.79	49.09	4.44	34.80	1.88	0.9	204	11.1	4427	4908	54.40	48
37 Grand Isle	87.70	12.30	45.56	4.61	34.84	2.69	1.0	219	9.9	4173	4757	51.93	33
10 Lamolle	83.72	16.28	44.70	3.69	33.21	2.12	1.1	224	12.1	3852	4600	53.40	40
Orange	80.21	19.79	42.83	4.35	30.38	2.65	1.2	234	9.8	3994	4979	53.40	30
6 Orleans	85.80	14.20	46.80	4.30	32.36	2.34	1.0	214	10.9	4253	4958	54.53	37
Rutland	62.14	37.86	34.39	3.21	22.43	2.11	1.8	291	10.7	3171	5103	55.34	29
Washington	87.33	12.67	47.65	4.89	32.15	2.64	0.9	210	9.7	4521	5179	54.53	33
18 Windham	69.16	30.84	37.72	3.61	25.92	1.91	1.5	265	10.4	3480	5034	54.54	36
12 Windsor	84.03	15.97	46.36	4.55	31.14	1.98	1.0	216	10.2	4349	5167	55.17	42
Average.....	82.58	17.42	44.56	4.23	31.57	2.22	1.1	224	10.6	4071	4930	53.96	37

SUMMARY BY COUNTIES (EXCLUSIVE OF SAMPLES CARRYING OVER 25% ASH)

Sample number	COMPOSITION OF DRY MATTER					FUEL VAL. RATIOS				FUEL VALUES			
	Organic and volatile matter, %	Crude ash, %	Carbon, %	Hydrogen, %	Oxygen and sulphur, %	Nitrogen, %	Carbon to oxygen and ash, 1 :	Carbon $\times 100$, 1 :	Hydrogen to carbon, 1 :	Calories (calculated)	Calories (calculated) on ash free basis	Carbon content (on ash free basis)	Nitrogen to organic & volatile matter, 1 :
Addison	88.22	11.78	47.91	4.30	33.39	2.62	0.9	209	11.1	4302	4876	54.30	34
Bennington	86.50	13.50	46.78	4.36	33.07	2.29	1.0	214	10.7	4248	4911	54.07	38
Chittenden	92.96	7.04	52.04	4.87	34.20	1.85	0.8	192	10.7	4832	5200	55.99	50
Franklin	91.97	8.03	50.23	4.52	35.33	1.89	0.9	199	11.1	4530	4927	54.61	49
Grand Isle	88.22	11.78	46.87	4.65	35.00	2.70	1.0	218	9.9	4206	4770	52.01	33
Lamoille	90.03	9.97	48.83	4.09	34.98	2.13	0.9	205	11.9	4272	4742	54.22	42
Orange	84.84	15.16	45.56	4.41	32.09	2.78	1.0	219	10.3	4183	5370	53.70	31
Orleans	90.48	9.52	49.82	4.42	33.91	2.33	0.9	201	11.3	4493	4967	55.06	39
Washington	92.17	7.83	49.84	5.24	34.69	2.70	0.9	201	9.5	4743	5141	54.04	34
Windham	93.26	6.74	50.32	4.92	36.14	1.88	0.9	199	10.2	4651	4987	53.93	50
Windsor	94.75	5.25	52.39	5.06	35.23	2.07	0.8	191	10.4	4891	5162	55.30	46
Average.....	90.09	9.91	48.71	4.61	34.48	2.29	0.9	205	10.5	4452	4942	54.06	39

SUMMARY BY COUNTIES (EXCLUSIVE OF SAMPLES CARRYING OVER 10% ASH)

Sample number	COMPOSITION OF DRY MATTER						FUEL VAL. RATIOS			FUEL VALUES			
	Organic and vola- tile matter, %	Crude ash, %	Carbon, %	Hydrogen, %	Oxygen and sulphur, %	Nitrogen, %	Carbon to oxygen and ash, 1 :	Carbon $\times 100$, 1 :	Hydrogen to carbon, 1 :	Calories (calcu- lated)	Calories (calcu- lated) [on an ash free basis]	Carbon content [on an ash free basis]	Nitrogen to organic & volatile matter, 1 :
Addison	7 91.40	8.60	49.82	4.04	34.97	2.57	0.9	201	12.3	4323	4730	54.51	36
Bennington	7 90.55	9.45	47.74	4.96	35.48	2.37	0.9	209	9.6	4457	4923	52.61	38
Chittenden	20 94.74	5.26	53.69	5.12	34.26	1.67	0.7	186	10.5	5058	5339	56.67	57
Franklin	13 92.92	7.08	50.86	4.46	35.79	1.81	0.8	197	11.4	4551	4898	54.74	51
Grand Isle	21 91.10	8.90	48.83	35.64	2.83	0.9	209	9.9	4403	4833	52.47	32	
Lamoille	6 94.10	5.90	50.28	4.17	37.55	2.10	0.9	199	12.1	4342	4612	53.40	45
Orange	2 92.86	7.14	51.64	5.07	33.60	2.55	0.8	194	10.2	4867	5242	55.60	36
Orleans	4 93.95	6.05	52.03	4.65	35.14	2.13	0.8	192	11.2	4721	5023	55.37	44
Washington	3 92.17	7.83	49.84	5.24	34.69	2.70	0.9	201	9.5	4743	5148	54.07	34
Windham	4 97.07	2.93	52.35	5.33	37.92	1.47	0.8	191	9.8	4918	5061	53.93	66
Windsor	9 94.75	5.25	52.39	5.06	35.23	2.07	0.8	191	10.4	4891	5162	55.30	46
Average.....	96 93.05	6.95	50.68	4.79	35.40	2.18	0.8	197	10.5	4650	4995	54.47	43

MISCELLANEOUS ANALYTICAL RESULTS

The samples taken during 1904 in Grand Isle and Chittenden counties, being Nos. 1-82 inclusive, were tested according to the old Fresenius method for fixed carbon or coke, by burning as nearly as may be out of access of air, the residue, less the ash, being considered fixed carbon. The various samples proved highly unlike as to the proportions of fixed carbon they carried, ranging from a negligible figure, in some samples not properly peat in character, to nearly 60 percent. A high coke content is indicative of high fuel value. The following samples rated relatively high in this respect carrying by this rather crude test over 45 percent of fixed carbon on a dry matter basis.

No.	Location	Owner	Coke %	Ratio of
				ash to coke 1:
6.	Grand Isle,	S. P. Gordon.....	45.1	7.9
59.	Grand Isle,	Lyman Swamp turf.....	49.4	4.8
68.	South Burlington,	L. A. & A. A. Drew Estate.	48.4	14.7
69.	Ditto.	.....	57.1	11.9
72.	Ditto.	.....	49.7	19.8
73.	Ditto.	.....	49.1	11.4
74.	Ditto.	.....	48.6	7.4
75.	Ditto.	.....	46.8	7.8
78.	Ditto.	.....	49.7	14.0
79.	Ditto.	.....	59.9	8.9

A comparison of the soluble and insoluble ash contents of the samples drawn in 1904 (Nos. 1-82) was also made. About one-third of the samples carried very high ash contents and most of these were only partially analyzed. The residue—53 in number—carried varying but not excessive quantities. Only three contained materially more insoluble than soluble ash, twelve in all carried more, while in 40 cases the soluble ash was either in excess of or equal to the insoluble. Speaking broadly, therefore, save where considerable soil infiltrations have occurred, the acid-soluble ash content usually exceeded the insoluble ash content. Lime salts were very generally—and naturally—present in the peat ashes, being present in large amounts in the samples show-

ing high soluble ash contents. Phosphoric acid was also qualitatively determined in a few of the ashes.

Eight samples, carrying from 2.76 to 4.07 percent nitrogen on a dry matter basis, were tested for availability of the organic nitrogen by the alkaline permanganate method as then (1905) used. The method as compared with the modification now employed tended to give high results. The availability percentages ranged from 23 to 34 percents. There appeared no relation between the total nitrogen contents and the slight differences in availabilities as thus measured. The nitrogen in peat and muck is well known to be but slowly available. Its solubility may be hastened, however, by composting it with barn yard manures as outlined on page 169.

VII. DISCUSSION OF THE ANALYTICAL RESULTS

The mass of figures appearing in the tables on pages 204 to 220 is not alluring. No one will be likely to read them through. Moreover their interpretation may well be difficult to the interested bog owner, even with the aid of the several pages of explanatory matter preceding them on pages 179 to 197. It seems on this account desirable to make some brief statement concerning each deposit, and such the matter on the succeeding pages is meant to furnish.

By way of disclaimer it ought to be said that the statements, both favorable and unfavorable, are, of course, predicated on the results secured with the samples in hand. While considerable care was taken in sampling, and the work was done by one of the writers who has had long experience in sampling fertilizers, feeds, milks, etc., as well as chemical laboratory experience, yet it may well be that the samples were not in all cases thoroughly representative. Anyone who contemplates making large use of any of the deposits herein referred to, should make further investigation both as to the extent of the deposit and the quality of its contents before investing efforts or funds therein. The Station will be glad to assist any resident in such investigation

to the extent of making analyses, if the number of samples submitted are not excessive.

CONCERNING THE SEVERAL DEPOSITS REPRESENTED BY THE
ANALYSES IN TABLES ON PAGES 204 TO 220 AND DESCRIBED
ON PAGES 179 TO 197

ADDISON COUNTY

(See description of samples from this county on pages 189 to 191 and analyses on pages 204 to 205).

Bridport. The Pratt swale meadow muck ought to be worth using for fertilizing purposes, since it carries $2\frac{3}{4}$ percent nitrogen; the older meadow deposit is not quite as good. The ratio figures of nitrogen to organic and volatile matter are low.

Bristol. The Bristol pond peats are of good quality. Their ash contents are low, their fuel ratios and values satisfactory (3,900-5,000 calories), their nitrogen contents average. Indeed No. 142, the silt-like material from the pond proper, is very rich in nitrogen and the ratio figure (23) is low, indicating richness. It is largely organic, only one-sixth being of mineral origin. The pond is well nigh filled therewith, and it would seem as if it were worth using locally as a soil amendment. Bristol and Starksboro farmers ought to look into the possibilities of this large deposit as a source both of fuel and of fertilizer. (See Plate IV.).

Monkton. The 50 acre Baldwin bog contains a fair grade of product of average fertilizing and average fuel value.

Shoreham. The Shoreham swamp is about a mile square. Its peat deposit seems to be mostly of wood and sedge origin. No moss occurs. The nitrogen content of the sample representing the center was high; of that drawn within the swale belt, lower. The ratio figures run low indicating good grade. The fuel value of the main bog deposit was fair; that from the swale belt rather low. The deposit in this swamp should be used for fertilizing purposes, and it would make fair fuel. (See Plate V.).

l'ergennes. The Booth estate peat has been used as a fertilizer for a long time. Its quantity is ample, its quality is excellent, the results attained are eminently satisfactory. Its fuel value is also high. This was one of the few deposits represented in this survey, of which proper use is being made. Both fuel and fertilizer ratios tell a good story.

BENNINGTON COUNTY

(See description of samples from this county on pages 181 to 182 and analyses on pages 204 to 207).

Bennington. The various deposits in this town rank as a class from average to rather low. The only passable ones from the fuel standpoint are the surface moss layer and the bottom peat of the Bald Mountain deposit No. 153 and the lower stratum from the Rice place No. 123. The latter, together with the surface layer, No. 122, carries a goodly nitrogen content, as do also the black mucks on the Rockwood and the West places (Nos. 161, 201), which have been extensively used for fertilizing purposes by their owners and their neighbors. (See Plate VI.).

Manchester. The Thomson muck bed looks like an everyday meadow, but it carries a high nitrogen percentage and a fair fuel content.

Shaftsbury. The 7 acre swamp area located on the Peleg Cole estate consists largely of a very deep reddish brown muck, carrying a high nitrogen percentage and fully average fuel values. It is well located near the railroad and might on this account be worth looking into, since transportation problems are thus to some extent simplified.

CHITTENDEN COUNTY

(See description of samples from this county on pages 182 to 185 and analyses on pages 206 to 209).

Charlotte. The Horsford farm cranberry meadow, 25 acres or more in extent, is a muck rather than a peat, high in ash, low in carbon, and rather high in fertilizing value, its nitrogen being well above the average, the ratios showing concentration. It

has been used as a cranberry meadow and dug as a fertilizer. (See Plate VII.).

Colchester. The Barstow estate area consists of several acres. It is located near the Rutland Railroad and hence its products, if ever marketed, could be readily transported. The carbon percentages shown in two samples from this deposit are high, 53 percent, the calories, 5,000; and, too, the nitrogen content is high. Unfortunately the bog is not one which seems capable of easy drainage.

Jericho. The Jordan Bros. meadow bog, together with adjacent and adjoining areas, covers considerable territory. The deposit is quite deep, is somewhere above the average in quality for fertilizing purposes, although the ratios do not read very well, and would rank fair to good as a source of fuel. A cranberry swamp, formerly owned by Dr. B. H. Stone, seems to contain a product which is less satisfactory as a fertilizer than the Jordan peat but is of about the same grade as a fuel. The Jordan bog is accessible and the Stone bog hard to reach.

South Burlington. The 100 acre Drew area is thoroughly described on pages 194-195. Eighteen analyses were made of as many samples drawn therefrom. Without going into details it may be said that it is perfectly clear that this deposit ranks low as a source of nitrogen. But one lone sample shows a satisfactory nitrogen percentage and that is so anomalous, so unlike its mates, that one cannot help but query as to the accuracy of sample or analysis. The deposit is clearly of little use as a source of nitrogen, though, of course, it would yield humus. Its fuel value, however, is another story, for it ranks high in this respect. Ten samples of the eighteen carried over 55 percent carbon and over 5,000 calories, while the ratios, which tell the story in a nutshell, are most satisfactory. Practical tests have shown that the peat from this bog makes an intense fire. (See Plate IX.). Its owners have queried as to the advisability of attempting to use it as a peat fuel supply. It might very well be used in the same way that the Franklin bog has been used. (See

pages 158-162).

Westford. The samples from the Nichols meadow basin are so highly dissimilar and the results so variable that one feels somewhat reluctant to generalize concerning them. If the material represented by No. 209, the upper black layer, is plentiful, the owner has an ample nitrogen supply at his command. (See Plate X.).

FRANKLIN COUNTY

(See description of samples from this county on pages 186 to 187 and analyses on pages 208 to 209).

Franklin. The big 200 acre cranberry marsh is quite fully described on page 196. The deposit is ill fitted for use as a fertilizer, the ratio figures being high, but its fuel value is considerable. It is a great mass of peat moss, inadequately drained. Were it nearer a railroad it might prove worth using for some of the subsidiary purposes indicated on page 167, but it is too far away from ready transportation. (See Plate VIII).

The Willard farm deposit, 50 acres in extent, is described on page 196. It has been used as a source of fuel for years as described on pages 158-162. The top peat is well above the average in fuel value; the bottom peat is not. These statements may be reversed as regards the nitrogen contents of the two samples. The reader is urged to read Mr. Webster's statements on pages 158-162; to note the reason why his trade fell off as indicated on page 196; and to take warning in case he contemplates using peat as a fuel to provide ample storage room for the large amount of light, fluffy ash which forms. (See Plates I, II, IX, XV, figures 1-3).

Highgate. The Jewett farm deposit, 50 acres in extent and deep, is of high grade as a source of fuel supply, but somewhat below par as a purveyor of nitrogen. It was formerly but unsuccessfully worked as a source of peat fuel, a result which has often attended efforts of this sort in this country.

Richford. The Pattee deposit, 40 acres in extent and 15 or more feet deep, is evidently one which is worthy of consideration as a source of fuel and also as a nitrogen supply. The carbon percentages and the calories are relatively high and the nitrogen contents above the average, though the ratios are not.

It is interesting to note that these three Canadian line towns possess extensive high grade fuel deposits, not outranked elsewhere in the state.

GRAND ISLE COUNTY

(See description of samples from this county on pages 188 to 191 and analyses on pages 210 to 213).

The samples collected in this county from bogs located close to Lake Champlain and subject to overflow during the spring high-water period show relatively large mineral matter contents in the upper layer samples. This is due to the water deposition. (See Nos. 28, 27, 26 and 29 drawn from a basin which fills from the lake every spring and is a popular fishing ground for pickerel shooters. See also Nos. 46 and 45). Doubtless the wind is also a factor in the high mineral matter content of the lake region peat, especially in the sandy regions.

Alburg. The Lyman swamp is an extensive deposit of hardly average quality, being below par both as a fuel and as a fertilizer. It is underlain with marl. The sample representing the bottom layer showed a fair fuel value, the sample representing the edge a good nitrogen content. In view of its size and the underlying marl it may be worth further reconnaissance.

The Canadian line swamp may or may not be worth while as a source of fuel supply, according as to whether sample 50 or sample 56 truly represents the bulk of the deposit, the one being low, the other good in this respect. The nitrogen percentages were average.

The samples from the Mott farm swamp, a cat-tail bog, tested high in nitrogen and from low to medium in carbon.

Grand Isle. The Davis farm deposit is a thick muck of fair quality of fertilizing purposes; the Adams marsh near the "Landing" is hardly more than a rich soil with plenty of muck in it; and the Gordon marsh, a lakeside deposit, is of average quality as a fertilizer. (See page 237).

The Hyde black muck overlies a shell marl bed and carries medium fuel and rather better than medium nitrogen contents.

The Pearl lakeshore swamp samples were but partially analyzed and show high ash contents and consequently low nitrogen percentages. One sample, No. 1, carries a satisfactory amount. (See page 237).

The Reynolds cedar swamp carried a high nitrogen and a fair carbon content; a good fertilizer, not so good a fuel source.

Isle La Motte. The H. H. Hill farm swamp outranks all the others included in this survey in fertilizing values, the four samples testing 3.62, 3.62, 4.19 and 2.45 percents nitrogen. Samples submitted to the Station in previous years have tested from 2.64 to 3.21 percent nitrogen (page 237). The deposit is a veritable gold mine of fertility. It has been used in the past with good results. The fuel values are fair. This deposit is too good for fuel purposes, however, and ought to be used as a fertilizer throughout the island. (See Plate XI.).

North Hero. The Allen's Creek swamp contains a deposit which is fairly rich in nitrogen and is of fair fuel value. (See also partial analyses page 237).

W. B. Dodds' one hundred acre lakeside marsh is a close competitor for first rank with the Isla La Motte deposit. Indeed the average nitrogen content of the five samples slightly exceeds that of the four samples from the Hill farm. It is a most satisfactory deposit for use in fertilization. Doubtless there are none better in Vermont. Its fuel value is fair also. With so large a deposit at hand its owner needs to buy but little nitrogen or to burn much wood. Nature has placed at his door an almost inexhaustible fuel and fertilizer supply which he can secure at a low cost. No other page of analytical data resembles page 221

so far as its right hand column is concerned. The low ratio figure is in almost constant view, emphasizing the great value of these deposits as sources of nitrogen.

The Dubuc farm swamp contains a deposit well worth using for its nitrogen content and of fair fuel value.

The Macomber twenty-acre lakeside deposit, as judged by one complete and two partial analyses, is of good quality as a fertilizer. One sample tests low, the other two high in nitrogen. The ash contents are relatively high and are responsible for the single low nitrogen.

South Hero. The Allen creek (South Hero) marsh seems, as judged by a single sample, to be of high grade as a source of nitrogen.

The S. P. Gordon estate deposit is a portion of the famous Pearl marsh covering over 100 acres. It has been extensively used as a fertilizer, yet its nitrogen content is very low and its ratios far up in the high figures. Its organic matter content—and hence its potential humus—is extremely high, its carbon content among the highest in the whole survey, and its calories well in excess of 5,000. This peat ought to make an admirable fuel, and, doubtless, has done well as a fertilizer, despite its low nitrogen percentage.

A thin layer on the Phelps farm is half mineral matter and not over rich in nitrogen.

Round pond, a small one acre location described on page 190, affords a peat which is of high quality from the point of view of the feeder of plants, but of rather poor quality from that of him who feeds fires, the calorie figures being distinctly low. The pond silt, No. 24, is an interesting material, high in its ash and its nitrogen contents. It ought to prove an excellent soil amendment.

LAMOILLE COUNTY

(See description of samples from this county on pages 191 to 192 and analyses on pages 212 to 213).

Johnson. The 100 acre bog on B. A. Hunt's place, together with the nearby Sterling pond deposit, are of average quality as purveyors of nitrogen, as shown by the low fuel ratios, and better than average as fuel furnishers. The inaccessibility of the deposit and its many water areas make it rather difficult to work. For local use as a source of plant food its product might be worth while.

The Edward Magoon muck bed is really a meadow which is cropped for grass. The muck lies from 6 to 12 feet deep, however, and is admixed with soil, ash percentages being high and fuel values consequently low. The nitrogen content is fairly good in view of the high mineral matter figures. The owner states that hay crops are light. The chances are that mineral fertilization would better the crop. It were well if potash were used on one strip, available phosphoric acid on another, insoluble phosphoric acid (floats) on another, lime on another, and phosphoric acid and potash on yet another. The accessibility of this deposit, and the fact that it is well drained, as well as its size and depth, ought to conspire make it a favorite resort for those in the vicinage who need such a soil amendment.

These samples (Nos. 226-229) represent a tilled meadow land deposit. That which represents the top layer carried quite a good deal more ash than did the two samples drawn well down in the deposit. The sample taken far down showed a high content of mineral matter indicating thus that the bottom of the deposit was at hand. This apparent anomaly, a high surface ash content, is quite apt to occur in a tilled area. It is doubtless in fact due to the greater oxidation and destruction of the organic matter thereof caused by tillage operations and to the consequent relative concentration of the unaltered mineral matter.

ORANGE COUNTY

(See description of samples from this county on page 192 and analyses on pages 212 to 213).

Vershire. The George estate swamp contains a shallow deposit of good fertilizing value, but having only medium fuel value.

West Fairlee. The twenty acre Knight Bros. wild meadow seems of uneven quality. One sample is distinctly inferior, while two are superior as fuels and fair to good as fertilizer. If its use is contemplated further investigation should be made as to its worth.

Williamstown. The W. C. Pratt area is a deep black muck of considerable fertilizing value and low fuel value, apparently well worth digging and using. Its average hay crop might be bettered if the trials suggested in the case of the Lamoille county meadow were employed.

ORLEANS COUNTY

(See description of samples from this county on pages 192 to 193 and analyses on pages 214 to 215).

The 100 acre Vance estate basin swamp might both feed and warm its owner. The samples drawn in the wooded area and from the bottom layer in the clearing, are better than the average in nitrogen; and all the samples taken in the clearing are of high fuel value. Located far from the railroad it can enjoy but local usage, but for such purposes it seems well worth while and nearby farmers ought to make use thereof.

Glover. The Runaway pond meadow deposit described on page 192 is rich in nitrogen despite its high content of mineral matter, but it is low in fuel value. The beneficial effect of wood ashes noted by the owner indicates that either a potash fertilization or liming would be likely to prove advantageous.

RUTLAND COUNTY

(See description of samples from this county on pages 193 to 194 and analyses on pages 214 to 215).

Benson. The 40 acre deposit on Strong Bros' farm is a unique one. It has a very low fuel value, but being mingled marl and muck ought to be highly beneficial as a soil amendment. (See Plate XII.).

WASHINGTON COUNTY

(See description of samples from this county on page 194 and analyses on pages 214 to 215).

Marshfield. The Dwinell 40 acre beaver meadow is a very deep deposit of good grade as a fertilizer, but of indefinite grade as a fuel, either poor or good according to the sample.

The 30 acre Ennis deposit has been largely used for fertilizing purposes for years, and is worthy such use. Its fuel value is also well above the average. (See Plate XIII.).

WINDHAM COUNTY

(See description of samples from this county on pages 194 to 196 and analyses on pages 214 to 217).

Stratton. Mud pond, a 10 acre sheet surrounded by a shallow peat layer, is not a very promising source of supply, the deposit being relatively small and of low grade.

The A. J. Pike property includes one of the most extensive areas in Vermont and likewise one of the most inaccessible. The "cranberry meadow" lot is the second best of three distinct locations as a source of fuel, and the poorest as a supply of nitrogen; the "reed meadow" furnishes the richest deposit for fertilizing purposes and the poorest fuel; and one sample from the huckleberry meadow as high fuel value and from low to medium fertilizing value. All the deposits are very deep and, also, are deep in the woods where fuel lies around on every hand. On account of their location there seems little likelihood that these deposits will ever be used.

Westminster Station. The Taylor 50 acre bog is an anomaly; a high grade material as judged by appearance, of low fuel value and rather inferior fertilizing worth as judged by the less erring verdict of chemical analysis. All the samples carried very high ash contents. The deposit is a muck soil rather than a muck. The fertilizer value ratio figures are low, indicating that the organic matter proper is rich in nitrogen. It is extremely accessible, being on both railway and highway; but the deposit is below grade because of soil admixtures. (See Plate XIV.).

WINDSOR COUNTY

(See description of samples from this county on pages 196 to 197 and analyses on pages 216 to 217).

Chester. J. A. Chandler and John A. Clark, located on adjoining farms, own between them 50 acres of deep muck. That on the Chandler place, as judged by the samples, is below grade; that on the Clark place is of high grade as a fuel and fully average as a fertilizer.

Ludlow. The Barton bog is a small sphagnum area, yielding a high fuel product which has been used as fuel and for agricultural purposes to good advantage. It is better adapted to use as fuel than as a fertilizer, its nitrogen content being low. It weathers readily to a fine powder and should make an admirable absorbent.

Woodstock. A single sample representing a pond deposit on the Billings farm shows good fuel and fair fertilizing value. It has been used as fertilizer to good advantage.

VIII. ANALYSES OF SAMPLES FORWARDED FOR EXAMINATION, 1888 TO DATE¹

ADDISON COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
7	L. W. Peet, Cornwall.....	68.25	31.75	3.35
17	Geo. Stokes, Starksboro	44.42	55.58	1.65
17	G. B. Mills, Monkton Ridge.....	26.75	73.25	0.91
	A. W. Hawkins, Ferrisburgh	55.60	44.40	1.78

The Cornwall sample, if representative, indicates a good deposit for use as a fertilizer.

BENNINGTON COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
8	F. F. Gilbert, Dorset .....	.....	.....	2.41
8	E. C. Orvis, Manchester	78.45	21.55	2.81
	Ditto,	57.03	42.97	2.00
	Ditto,	28.24	71.76	1.07
9	Ditto,	82.30	17.70	3.03
10	Miss C. de Nottbeck, Dorset.....	47.25	52.75	1.71
	Ditto,	28.79	71.21	1.04
	Henry Harrington, So. Shaftsbury.....	50.82	49.18	1.67
	P. B. Jennings, Bennington Center.....	36.27	63.73	1.29
	E. J. Hood, Manchester Depot.....	68.23	31.77	1.73
	Ditto,	87.75	12.25	2.70
	S. E. Harwood, Bennington.....	85.95	14.05	2.36
	J. D. Purdy, Manchester	53.38	46.62	1.97
	Ditto,	55.28	44.72	2.12

Certain of these samples indicate deposits of good grade as a fertilizer. Two of the Orvis samples and one of the Hard samples, all from Manchester, carried relatively high nitrogen contents.

¹ Including 23 samples from Grand Isle county, taken in the survey work and not completely analysed.

CALEDONIA COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
1	A. B. Carpenter, West Waterford.....	.....	.....	1.54
1	Ditto, .....	.....	.....	2.71
9	A. B. Stoddard, West Burke.....	78.61	21.39	2.74
9	C. I. Smith, McIndoes	19.94	80.06	0.80
9	Ditto,	64.61	35.39	2.16
	O. H. Park, West Burke.....	25.06	74.94	0.94
	Ditto,	86.69	13.31	2.49

The second Carpenter, the Stoddard and the second Park sample proved well worth while as purveyors of nitrogen.

CHITTENDEN COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
4	Elias Lyman, Burlington .....	.....	.....	1.62
7	M. A. Maynard, Burlington.....	.....	.....	4.04
8	O. K. Fletcher, Hinesburg .....	.....	.....	1.37
9	C. M. Scarff, Burlington	73.71	26.29	2.07
12	Geo. Alger, Underhill	87.93	12.07	2.03
	Ditto,	96.44	3.56	0.90
15	L. A. Drew, Burlington	50.00	50.00	1.21
17	H. A. Parmelee, Milton	35.45	64.55	1.59
	Edward Krupp, Williston	60.47	39.53	1.65
	G. H. Perkins, Burlington.....	47.70	52.30	1.37
	Miss Genevieve Horsford, Charlotte....	74.47	25.53	2.68

Two samples in the lot are notable; the Maynard sample, testing over 4 percent nitrogen, and the Drew sample—doubtless from the deposit discussed on pages 184-185, carrying over 60 percent of organic and volatile matter. The Horsford sample is also of good grade and doubtless represents the deposit discussed on page 183.

FRANKLIN COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
3	John Webster, Franklin	89.63	10.37	....
3	Ditto,	92.85	7.15	....
5	L. H. Felton, Highgate	92.73	7.27	....
5	Ditto,	79.47	20.53	....
5	Ditto, .....	.....	.....	2.27
6	John Webster, Franklin	65.87	34.13	2.10
9	John Spooner, Enosburg	89.48	10.52	2.52
9	M. F. Sullivan, St. Albans.....	94.56	5.44	2.16
10	Louise C. Hunt, Fairfax	63.90	36.10	1.95
	J. C. Place, St. Albans	28.95	71.05	0.81
	Ditto,	18.55	81.45	0.60
	G. R. Kenfield, Enosburg Falls	36.60	63.40	0.49
	E. C. Smith, St. Albans.....	61.45	38.55	2.40
	Ditto,	43.47	56.53	1.17
	L. H. Felton, Highgate	69.09	30.91	2.39
	Ditto,	87.50	12.50	3.22

Several of these samples are of high grade; two of the three Webster samples (see pages 158-162, 186), some of each lot of the Felton samples, which probably represent the deposit described on page 187; the Spooner and the Sullivan samples. All these are of an excellent character.

ESSEX COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
	S. T. Bickford, Beecher Falls.....	96.56	3.44	2.57

This sample is of good grade both as fuel and as a source of nitrogen.

GRAND ISLE COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
12	L. H. Sowles, Alburg	77.08	22.92	1.69
No. 1	Lucy Pearl, Grand Isle; lakeshore swamp; 2 feet down.....	68.89	31.11	2.75
No. 2	Ditto, center	44.31	55.69	1.59
No. 3	Ditto, cedar growth	52.31	47.69	1.73
No. 4	Ditto, edge cattail swamp, 5 feet down	48.76	51.24	1.76
No. 5	P. Gordon, Grand Isle; lakeshore marsh 5 feet down	49.10	50.90	2.00
No.13	E. J. Parker, Grand Isle; small bog; black muck; shelly	35.71	64.29	1.43
No.14	Davis Farm, Grand Isle; black muck, 1 foot deep	59.31	40.69	2.28
No.20	Adams marsh, Grand Isle; shallow....	23.92	76.08	1.06
5	H. H. Hill, Isle La Motte.....	.....	.....	2.64
5	Ditto, .....	.....	.....	3.06
5	Ditto, .....	.....	.....	3.21
No.60	Ditto, edge of swamp; clay 1 foot down	30.70	69.30	1.29
10	M. S. Thomas, Isle La Motte.....	87.30	12.70	3.13
13	O. J. Thomas, Isle La Motte.....	59.37	40.63	2.00
	T. L. Kinney, South Hero.....	83.64	16.36	3.91
No.21	A. Landon, South Hero; Round pond, bottom 3½ feet deep, wooded fringe	10.63	89.37	0.35
No.22	Ditto, middle, Do.	45.57	54.43	1.41
No.23	Ditto, top, Do.	35.93	64.07	1.18
No.30	E. Phelps, South Hero; under sand; very thin; near lake	46.24	53.76	2.16
No.32	Allen creek marsh, South Hero; near surface average	49.26	50.74	2.08
No.33	Ditto, upper layer	75.97	24.03	2.89
No.34	Ditto, bottom, 2 feet deep.....	64.19	35.81	2.25
No.35	Ditto, (wooded part)	64.58	35.42	2.49
No.41	Ditto,	82.11	17.89	2.85
No.42	Allen's creek, top of 6 foot excavation.	71.20	28.80	3.08
No.47	Macomber, 20-acre swamp, near lake- side	28.80	71.20	1.31
No.48	Ditto,	60.37	39.63	2.50

Most of these samples were taken in the regular way by one of the writers (F. M. H.), but were not completely analyzed, usually because of high ash contents. The Hill samples sent for analysis 20 years ago, doubtless represent the deposit described on page 189. The Thomas and Kinney samples are well worth while as a fertilizer; and so are the Allen creek marsh samples and the second Macomber, despite their high ash contents.

LAMOILLE COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
9	C. M. Stebbins, Wolcott	32.20	67.80	1.04
12	F. A. Strong, Morrisville	64.60	35.40	1.44
13	H. E. Howard, Elmore	24.58	75.42	1.12
17	E. B. Sawyer, Hyde Park	48.22	51.78	1.69

These are all of poor quality.

ORANGE COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
3	S. M. Flint, Randolph .....	.....	.....	1.53
4	T. H. Wheatley, Brookfield .....	.....	.....	2.13
14	E. L. Bass, Randolph	92.15	7.85	1.59
14	J. L. Lang, Newbury	48.50	51.50	1.45
14	Ditto,	48.60	51.40	1.48
15	H. F. Emery, Thetford	85.56	14.44	2.86
18	Ditto,	92.36	7.64	2.79
	Byron Wakefield, East Braintree.....	10.19	89.81	0.32

The Randolph sample, if representative, is worth while as a fuel; the Thetford samples as fertilizers.

ORLEANS COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
10	E. K. Gray, Coventry	76.03	23.97	1.84
12	B. Lane, Newport	87.89	12.11	1.01
	H. S. Fisk, Orleans	38.35	61.65	1.59
	Ditto,	27.20	72.80	0.45

The Lane sample indicates fair fuel possibilities; the rest of the lot range from fair to nearly worthless.

RUTLAND COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
6	L. H. Sheldon, Fair Haven.....	.....	.....	2.81
8	J. N. Baxter, Rutland .....	.....	.....	2.42
10	H. G. Thompson, Pawlet	82.01	17.99	3.10
14	E. M. Buck, Rutland	79.35	20.65	1.85
14	Ditto,	71.94	28.06	2.34
15	B. W. Pennock, Rutland	61.22	38.78	1.40
	The Mead Farm, Rutland.....	20.57	79.43	0.65
	Ditto,	74.65	25.35	1.84
	M. H. Smith, Rutland	53.32	46.68	1.94

The first three lots are well worth while for fertilizing purposes and is also the second Buck sample.

WASHINGTON COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
7	E. G. Tuthill, Waterbury .....	.....	.....	2.71
10	N. C. Bradley, Warren	64.87	35.13	1.67
10	H. B. Chapin, Middlesex	87.36	12.64	1.55
	W. J. Chamberlain, East Barre.....	77.24	22.76	2.52

The first and last samples carry good nitrogen contents; the others are but fair in this respect.

WINDHAM COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
8	W. L. Sylvester, West Brattleboro.....	26.40	73.60	1.47
9	C. M. Densmore, Jamaica.....	96.55	3.45	1.82
9	Ditto,	97.77	2.23	1.40
9	M. R. Robbins, Brattleboro.....	75.36	24.64	2.01
10	D. C. Wright, Westminster Station....	85.50	14.50	2.11
	J. P. Helyar, Brattleboro	23.26	76.74	0.70
	E. G. Tuthill, Westminster.....	27.00	73.00	0.73

The samples from this county run low in nitrogen, but the Jamaica deposit ought to burn well.

WINDSOR COUNTY

Rpt.	Name and address	DRY MATTER BASIS		
		Organic and volatile matter	Ash	Nitrogen
6	Geo. Altken, Woodstock	80.70	19.30	3.58
6	Ditto,	91.07	8.93	1.79
12	L. W. Barton, Ludlow	97.23	2.77	1.45
12	Ditto,	74.10	25.90	0.73
12	Ditto,	25.54	74.46	0.66
15	Ditto,	97.30	2.70	....
	A. Bugbee, South Royalton.....	27.99	72.01	0.97

The Woodstock and Ludlow samples doubtless were drawn from the deposits discussed on pages 196 and 197.

UNIV. OF MICHIGAN,
UNIVERSITY OF VERMONT
AND STATE AGRICULTURAL COLLEGE

VERMONT AGRICULTURAL
EXPERIMENT STATION

BURLINGTON, VT.

BULLETIN No. 166

JUNE, 1912

Commercial Fertilizers

- I. SUMMARY—Pages 243-244.
- II. INTRODUCTION—Pages 245-253.
- III. RESULTS OF FERTILIZER INSPECTION—Pages 253-273.
- IV. RELATION BETWEEN SELLING PRICE AND VALUATION—Pages 273-282.
- V. OBSERVANCE OF THE FERTILIZER LAW—Pages 282-307.
- VI. ANALYSES FOR FIVE YEARS—Pages 308-320.

BURLINGTON:
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1912.

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Address all communications not to individual officers but to the Experiment Station, Burlington, Vt.

Director's and State Forester's offices, chemical, horticultural and dairy laboratories are in Morrill Hall at the head of Main street; botanical and bacteriological laboratories are at Williams Science Hall, University Place; veterinary laboratories at 499 Main Street.

Experiment farm and buildings are on the Williston road, adjoining the University grounds on the east.

*In cooperation with Bu. An. Ind., U. S. Dept. Agr.

BULLETIN 166: COMMERCIAL FERTILIZERS

By J. L. HILLS, C. H. JONES, P. A. BENEDICT and W. B. DERBY

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SUMMARY

III Results of inspection. The Station has drawn from dealer's stocks and analyzed 182 licensed brands, the output of 19 companies, all this year's goods. Six licensed brands were not found on sale.

1. Quantity of plant food. Eighty-six percent of the brands met their guaranties. Three brands failed to afford a commercial equivalent of the promises made for them. The outcome on the whole is a thoroughly satisfactory one.

2. Quality of plant food. The quality of the crude stock used in furnishing phosphoric acid and potash seemed to be beyond reproach. The inferential claim that sulphate of potash was used, hitherto made for two-thirds of the brands, is now made for only one brand in four; only eight brands contained any appreciable quantities of sulphate. More mineral nitrogen is used nowadays than hitherto; even the low grade brands carry it. Organic nitrogen of low availability was found in a few brands, enjoying only limited sales, as is noted in the text. Pages 253-273.

IV Selling prices and valuations. The average selling price was \$32.03; the average valuation, \$20.09. One dollar in three spent for mixed fertilizers was paid to the manufacturer, railroad, and selling agent for their work, while but two of the three were paid for plant food. But 55 cents' worth of plant food was bought for a dollar in average low priced goods, and 59 cents' worth in medium priced goods. The average high priced brand, however, afforded 69 cents' worth for a dollar. Some Vermont consumers paid fully twice as much for plant food as did others. Pages 273-282.

V The analyses of the fertilizers sold in Vermont this year appear on pages 292-307.

VI A comparison of analyses of brands for five years shows in some cases essential evenness and in others considerable variation in composition. The table showing composition for five years should prove helpful to the early buyer of mixed goods. Pages 308-320.

II. INTRODUCTION

The fertilizer law enacted in 1902 provides that the yearly bulletins of the Station dealing with commercial fertilizers shall not only give the results of the analyses of these goods, but shall also publish "additional information in relation to [their] character, composition, value and use." It further directs that publication be made "as promptly as the progress of the analyses will allow and as frequently as time and means permit." The annual bulletin issued, if possible, early in July, discloses the analyses of all the brands collected, shows their composition during the preceding four and the current years, contains a general review of the trade of the State, makes statements as to the quantity and quality of the plant food sold in the sundry brands, considers the comparative values of the average goods of the current and preceding years, and outlines the relationship between selling prices and valuations.

These general matters are annually reviewed. In addition thereto there is yearly presented a somewhat full discussion of some special topic having to do with fertilization, a "feature" as it were.¹ This plan was inaugurated in 1902, and presumably will be pursued for several years to come. Thus the recipient of the bulletins who preserves them will in time possess a more or less complete treatise on the general subject of fertilization.

So far as possible technicalities have been, are and will be avoided and plain every-day language used. Yet many who read will find that careful attention will be needed. For the assistance of such, glossaries of definitions were supplied in bulletins 99, 130, 143 and 154. Probably these glossaries will be added to from time to time in the future. Anyone failing to grasp the meaning of the terms used should get bulletins 99, 130, 143 or 154 (if in print) and make use of their glossaries. The are free for the asking. The larger bulletin is always thoroughly indexed.

¹ The special feature is this year issued as a separate bulletin—No. 165—being a discussion of a survey of Vermont's peat and muck deposits.

The following statement outlines the "features" of the preceding bulletins:

Bulletin 93 (1902). *Formulas for home mixing.*—(56 pages). (Out of print).

Bulletin 99 (1903). *Vermont's usage of fertilizers. Concerning fertilizer buying. Deficient plant food.*—(88 pages). (Out of print).

Bulletin 108 (1904). *Classification of commercial fertilizers sold in Vermont. Farm manures.*—(68 pages).

Bulletin 116 (1905). *How, when and what to use.*—(104 pages). (Out of print).

Bulletin 123 (1906). *Concerning the purchase of plant food. The moisture relations of the soil.*—(68 pages). (Out of print).

Bulletin 130 (1907). *Soil biology in its relation to fertilization.*—(144 pages). (Out of print).

Bulletin 135 (1908). *A quarter of a century of fertilizer inspection. Soil deterioration and soil humus.*—(128 pages).

Bulletin 143 (1909). *The service of a fertilizer control. Soil physiography.*—(144 pages). (Available only as a loan).

Bulletin 154 (1910). *Soil classifications and adaptations.*—(112 pages).

Bulletin 160 (1911), *Limes and liming*, (144 pages).

Bulletin 165 (1912), *A survey of the peat and muck deposits of Vermont.* (104 pages).

These articles were written in 1902, 1903, 1904, 1905, 1906, 1907, 1908, 1909, 1910, 1911 and 1912; but they are as applicable to the purchase and use of fertilizers in 1912 and in succeeding years as they were when first penned. The reader of this bulletin who does not own a 108, a 135, a 154 or a 160, and wants either or all of them, has but to ask to receive. Nos. 93, 99, 116, 123 and 130 are out of print. No. 143, being nearly exhausted, is only issued on loan to those who will promise to return it after it has served their purpose. Circular No. 1—free for the asking—outlines all these bulletins except the last four

issued. Circular 7 on "Plant Food Combinations for Sundry Crops" contains a reprint of the more important formulas, etc., originally issued in bulletin 116.

THE FERTILIZER LAW (CHAPTER 213 P. S.)

The term "commercial fertilizer" is defined to mean "compounds and manufactured substances containing * * * two or more of the ingredients" (nitrogen, potash, phosphoric acid) but not "the separate ingredients used to manufacture the same, or * * * bone meal, land plaster, lime or a substance the product of nature which is not compounded." (Sec. 4973 P. S.)

It provides that "every lot * * * of commercial fertilizer * * * shall be accompanied by a * * * statement * * * certifying the number of net pounds, * * * the * * * brand, * * * the name and address of the manufacturer, * * * and a chemical analysis stating the minimum percentages of nitrogen, of potash soluble in distilled water, and of soluble, reverted, insoluble, available and total phosphoric acids, and the maximum percentage of chlorin." (Sec. 4976 P. S.)

It provides that the "manufacturer, importer, agent or seller" (the latter only in case the manufacturer fails to comply with the law) "* * * shall annually * * * pay * * * a license fee of twenty dollars," which will permit "the sale of one brand of commercial fertilizer which shall be the product of the licensee." It further provides that "if a manufacturer * * * desires to sell * * * more than one brand, he shall annually * * * pay a license fee of twenty dollars for each * * * brand * * * in excess of one." "The fee (s) * * * cover and authorize sales * * * for the calendar year." (Secs. 4977-4978 P. S. as amended by No. 169 of the Acts of 1910).

It provides that any person offering unguaranteed, overguaranteed or unlicensed goods shall be subject to a fine (Sec. 4981 P. S.); forbids the use of "leather or its products, hair, wool waste, garbage tankage or inert nitrogenous material" unless explicit notice thereof be made (Sec. 4980 P. S.); provides

that license fees be sent to the state treasurer, and for the reimbursement of the Experiment station for expenses incurred (Sec. 4982 P. S.); for sampling, analyses and publication (Secs. 4990 and 4991 P. S.); forbids interference. (Sec. 3993 P. S.); and prescribes the procedure in case of violation (Sec. 4989 P. S.). The act does "not apply to persons manufacturing, importing or purchasing * * * fertilizers * * * for their own use and not for sale in this State." (Sec. 4992 P. S.).

The full text of the law will be furnished on application.

LIST OF LICENSEES.

The following twenty companies have paid licenses as required by law on the brands shown in the statements on pages 249, 283 to 290 and in the tables on pages 292 to 307. The sale within the State of these brands, and of these brands only, is legal. All local agents, as well as intending purchasers, are warned against the handling of other brands, unless bought for personal use and not for sale. They are likewise warned against the sale of mixed goods of companies other than those listed herewith, since they render themselves liable to pay the twenty dollars license fee. "Parties manufacturing, importing or purchasing fertilizers for their own use and not for sale in this State" are not affected by the restrictions of the law.

American Agricultural Chemical Co., 2 Rector St., New York, N. Y.

Armour Fertilizer Works, 930-938 Equitable Building, Baltimore, Md.

Bowker Fertilizer Co., 43 Chatham St., Boston, Mass.

J. F. Bromley, Granville, N. Y.

Buffalo Fertilizer Co., Williams St., near City Line, Buffalo, N. Y.

Burlington Rendering Co., North Ave., Burlington, Vt.

Coe-Mortimer Co., 51 Chambers St., New York, N. Y.

Essex Fertilizer Co., 39 No. Market St., Boston, Mass.

Hubbard Fertilizer Company of Baltimore City, Keyser Building, Baltimore, Md.

Listers Agricultural Chemical Works, Newark, N. J.
 National Fertilizer Co., 92 State St., Boston, Mass.
 New England Fertilizer Co., 42 No. Market St., Boston, Mass.
 Parmenter & Polsey Fertilizer Co., 40 No. Market St., Boston, Mass.
 Reading Bone Fertilizer Co., 32-34 North Sixth St., Reading, Penn.
 Rogers and Hubbard Co., Middletown, Conn.
 F. S. Royster Guano Co., 1255 Calvert Building, Baltimore, Md.
 J. W. Sanborn, Pittsfield, N. H.
 Sanderson Fertilizer and Chemical Co., New Haven, Conn.
 Swift's Lowell Fertilizer Co., 44 No. Market St., Boston, Mass.
 Twentieth Century Specialty Co., 67 Freeport St., Boston, Mass.

COLLECTION OF SAMPLES.

The sampling agents of the Station visited 82 towns and villages in Vermont during the spring of 1912 and drew 353 samples from dealers' stocks, representing 182 distinct brands, the output of 19 companies licensed to sell in Vermont. A sample was secured of every brand which was licensed, save the following six, which, though licensed, were apparently not offered through agents this year.

Hubbard Fertilizer Co.'s Bone & Potash.

" " Crop Grower.

" " Farmers' IXL.

" " Special Potato Fertilizer.

" " Ten Percent Potash Guano for Potatoes.

Twentieth Century Specialty Co.'s 12 L.

SCHEDULE OF TRADE VALUES.

The following schedule of trade values to be used in this State in 1912 is the one agreed upon by the Experiment stations of New England and New Jersey, after a careful study of prices ruling in the larger markets. The 1911 schedule is also shown for the purpose of comparison.

TRADE VALUES OF FERTILIZING INGREDIENTS IN RAW MATERIALS AND CHEMICALS FOR 1911 AND 1912

	1911 cts. per lb.	1912 cts. per lb.
Nitrogen in nitrates	16	16½
Nitrogen in ammonia salts	16	16½
Organic nitrogen in dry and fine ground fish, blood and meat	23	22
“ “ in fine ground bone and tankage and in mixed fertilizers.....	20	19
“ “ in coarse bone and tankage.....	15	15
Phosphoric acid soluble in water.....	4½	4½
“ “ soluble in ammonium citrate¹.....	4	4
“ “ in fine ground bone and tankage..	4	4
“ “ in coarse bone and tankage.....	3½	3½
“ “ insoluble (in water and in ammonium citrate¹) in mixed fertilizers	2	2
Potash as high grade sulphate and in mixtures free from muriate (chlorid)	5	5¼
Potash as muriate	4¼	4¼

These trade values are, as nearly as can be estimated, the average figures at which, in the six months preceding March 1st, the respective ingredients could be bought at retail for cash in the larger markets (Boston, New York, etc.), in the *raw materials*, unmixed. They also correspond to the average wholesale prices for six months ending March 1st, plus about 20 percent in the case of goods for which there are wholesale quotations. The valuations obtained by the use of the above figures will be found to agree fairly with the reasonable average retail price in the large markets of standard raw materials.

In applying trade values to mixed goods, organic nitrogen is valued at 19 cents a pound; nitrogen as nitrate of soda and as sulphate of ammonia at 16½ cents a pound; soluble, reverted and insoluble phosphoric acids at 4½, 4 and 2 cents a pound respectively; and potash at 4¼ cents a pound, if there is sufficient chlorin to unite with all the potash; if not, it is valued at 5¼ cents.

A valuation is determined as follows: The percentages or pounds per hundred of each ingredient (i. e., nitrate nitrogen,

¹ Dissolved from 2 grams of the prepared sample, previously extracted with pure water, by 100 c. c. of a neutral solution of ammonium citrate, sp. gr. 1.09, in 30 minutes at 65 degrees C, with agitation once in five minutes.

ammoniacal nitrogen, organic nitrogen, soluble phosphoric acid, reverted phosphoric acid, insoluble phosphoric acid and potash), are multiplied by 20, giving the number of pounds of each ingredient in a ton. These figures are then multiplied by their respective pound prices.

THE MEANING OF COMMERCIAL VALUATIONS.

That there may be no misconception and that the reader may clearly appreciate what these valuations are and what they are not, it is our custom to call attention repeatedly to the fact that *a station valuation does not represent the proper selling price of a fertilizer at the point of consumption*. Neither should it be inferred that the ingredients in the brand in question have of necessity the commercial value indicated. It may be greater or less than is shown. The Station does not pretend dogmatically to state what may be the commercial worth of valuation of any one of the many brands of fertilizer sold in the Vermont market, as it cannot always affirm the quality of the crude stock used, particularly the nitrogenous material, although in a better position to do this today than hitherto. The valuation system is based on the assumption that all brands are composed solely of high grade ingredients, an assumption which is probably erroneous. "Valuations" should not be construed as showing the commercial worth of a given fertilizer, but the *retail trade value or cash-cost of amounts of nitrogen, phosphoric acid and potash, equal to those contained in a ton of the brand in question, in unmixed, standard raw materials of good quality, at the seaboard*. They bear no necessary relationship to the agricultural or the crop producing value of the goods, but simply indicate the current market prices of standard commercial articles, more particularly nitrate of soda, sulphate of ammonia, dried blood, tankage, ground bone, acid phosphate, muriate of potash, sulphate of potash and kainit.

Valuations thus construed, while not infallible, are helpful:

(a) To show whether a given fertilizer is worth its cost from the *commercial* standpoint.

(b) As a common basis on which to compare the *commercial* values of different brands, enabling buyers to note whether prices asked are warranted by values contained.

Valuations, then, simply show the cost of ready-made plant food. Its cost, however, is but one of the many charges which determine the retail cost of commercial fertilizers, just as the leather from which a pair of shoes is made is but one of the many charges which go to make up the retail cost thereof. The plant food must be also mixed, stored, reground, bagged, loaded, and freighted. Then, too, commissions to agents and dealers, the expense of selling on long credit, the item of bad debts, the interest on investments, the depreciation of the manufacturing plant, profits, etc., are also proper and fixed charges; yet not one of these so-called "overhead charges" contributes to plant growth. Commercial fertilizers are usually applied in the mixed form, but this is simply a matter of convenience, for as good results may be obtained by the application separately of the several crude ingredients.

An illustration may serve to make these statements more clear. A farmer buys in Boston or New York 50 pounds of nitrate of soda, 350 pounds of dried blood, 1,475 pounds of acid phosphate, and 125 pounds of muriate of potash, and he mixes these ingredients together at home on his barn floor, as thousands have done before him. The cost of this ton after mixing will be made up as follows: (a) Cost of material in the market; (b) cost of transportation; (c) cost of mixing. The first item (a) entering into the total cost is the only one included in the "valuation." If to (a) be added (b) (c), and, also, the expenses of selling through agents, long credits, bad debts, etc., we have the factors involved in the sale of fertilizers delivered in Vermont. Clearly the local selling price must of necessity exceed the "valuation." Since the cost of mixing and selling varies with different companies, and since freight rates to the different sections of the State are unlike, no arbitrary sum to cover these charges can be assigned. These can be estimated best by the con-

sumer to fit his local conditions. He should expect to pay and does pay not only for the plant food contents of his purchase, but also a fair margin to cover the expenses incident to assemblage, manufacture and sale, as well as for the convenience and other advantages pertaining to the use of ready-made and locally supplied plant food. If the selling price does not exceed the valuation by more than 35 or 40 percent it may not be too high, but in proportion as the excess increases beyond this point there is reason to question the economy of the purchase. The reader is referred for a further and somewhat full discussion of this matter to pages 340-345 of bulletin 160, also to the special article in bulletin 143, pages 183-192, dealing with the exposition of the meaning of the analyses and valuations.

III. RESULTS OF FERTILIZER INSPECTION.

I. AS TO QUANTITY OF PLANT FOOD.

(a) COMPARISON OF GUARANTIES AND ANALYSES.

The general quality of the brands sold in 1912 was on the whole not quite as good as was the case in 1910 and 1911. It was distinctly better, however, than that observed in the six years preceding 1910. While only 3 brands failed to afford the commercial equivalent of their guaranties, 26 brands, or 1 in 8, were in some respect deficient. It is but just to say, however, that 8 of this number were barely over the line, being but very slightly short in a single ingredient. Two brands were lacking in 2 ingredients. The shortages in commercial equivalents noted above were not "as wide as a barn door;" nor "as high as a church steeple," yet were considerable, being \$1, \$1.13 and \$1.69, amounts ranging from 3 to 7 percent of the purchase prices. Concerning these shortages it may be said:

The manufacturer of the brand which fails by \$1 to make good its promise states that "it is the intention of this company to give everything guaranteed; but under present conditions, at the price at which fertilizer is selling, it cannot afford

to go beyond that." Three different samples of this brand, two drawn at the same place at intervals and another drawn elsewhere, showed essentially the same shortage. It would seem that in the attempt not "to go beyond that" (giving "everything guaranteed") this company was somewhat too careful.

The manufacturer of the other two brands, \$1.13 and \$1.69 short of affording the commercial equivalent of their guaranties, states that "there must be a mistake." That a "mistake" may have been made in one case is granted, but not in the other. One of these brands was an extremely high grade goods, guaranteed to carry over 8.5 percent nitrogen. But a few bags were found on sale and sampled. It is well understood that goods of such high grade are relatively difficult to sample. They were found late in the season, and the goods had been used by the owner before a resample could be taken to check possible errors. However, in view of the fact that the sampling agent was sent specially for this brand and only had two or three bags to sample from, and in view of the distinctive character of these goods, there hardly could have been a mix-up in sampling. Furthermore, since goods of this kind are prone to mechanical separation in the bag, and because of the other reasons above mentioned, the Station lays little stress upon this shortage and believes that it is at least an open question whether the sample was or was not adequately representative. With the other goods, however, the case is different. The shortage in potash is extreme, only four-tenths of the amount guaranteed being found present. These goods as sold in other states in previous years have carried a low potash guaranty. The moment the serious shortage was discovered, the sampling agent was sent to the same point again to resample; but the goods had been entirely used, not even a bag being left. A careful scrutiny of the sampler's records, as well as thorough questioning, leads the writer to believe there can have been no error in sample taking. Such other goods as were in stock at the time of sampling were of such a grade as

would have tended to increase both the nitrogen and the potash contents of the sample. Had a sampling error been made, the questioned figure would have been larger than it is. The evidence at hand would seem to indicate that as a matter of fact the old grade of goods with the lower potash guaranty was shipped in lieu of the better grade.

The general situation is a good one, faulty fertilizers, as judged by the comparison of promise and performance, are not common, and the trade seems to be in a healthy condition. Comparison with the results attained in other states is a favorable one, since the proportion of guaranty maintainance is better than that commonly found elsewhere. Commercial fertilizers are shipped into Vermont earlier than in most other northern states. Whether to this fact or to other causes may be attributed the relatively small proportion of failure to furnish the promised plant food which obtains in Vermont cannot be said; but certain it is that as judged by several years' control work the Vermont farmer rarely buys a fertilizer of lower grade than that which the manufacturer promises to furnish him.

The plant food shortages in the 26 deficiencies were distributed, as follows: Nitrogen, 4; available phosphoric acid, 18; potash, 6. Only 6 of the 533 guaranties made on 182 brands by 19 manufacturers, or 1 in 90, were not made good within 0.50 percent of a single ingredient; and only 3 were lacking to an extent greater than 0.60 percent. This is a most excellent showing.

Whenever guaranties were not made good the analytical work was repeated, and invariably recourse was had to other samples taken a second time from the original shipments, except in cases where the goods were used prior to the determination of the shortage. In several cases when results seemed open to question, other samples elsewhere drawn were analyzed. Unusually high figures were similarly checked. Careful comparisons with the analytical results of previous years were also instituted with a view of minimizing error and standardizing results. This general procedure has been in vogue at this Station

for years, and is thought to minimize to the last degree the likelihood of error in sampling or analysis.

The condensed results of 18 years' inspection of the Vermont fertilizer trade, so far as they relate to the maintenance of guaranty, follow:

Year	Number of brands analyzed	Number of brands up to or above guaranty through-out	Number of brands deficient	Percent of total number up to or above guaranty	Percent of total number affording commercial equivalent of guaranty
1895	92	76	16	83	95
1896	110	91	19	83	99
1897	134	113	21	84	94
1898	126	113	13	90	100
1899	137	105	32	77	90
1900	132	114	18	86	96
1901	134	118	16	87	99
1902	136	123	13	90	100
1903	111	106	5	96	100
1904	118	94	24	80	97
1905	130	92	38	71	94
1906	130	110	20	85	98
1907	129	99	30	77	94
1908	130	92	38	71	95
1909	133	111	22	83	96
1910	152	138	14	91	100
1911	157	146	11	93	99
1912	182	156	26	86	98

The table on the next page shows the number of brands sold by the different companies licensed in Vermont, the number of guaranties (nitrogen, available phosphoric acid, potash) made by each, and the number of failures to make the same good within 0.10 percent of nitrogen or 0.20 percent of available phosphoric acid or potash.

Ten of the nineteen companies contribute brands to the delinquent list. Four furnish a single brand each; four, two apiece; one supplies four; and one, twelve brands.

MAINTENANCE OF GUARANTIES BY LICENSEES

Name of company	Number of brands	Number of guaranties	Number of guaranties not made good	Number of brands not making good the commercial equivalent of the guaranty
American Agricultural Chemical Co.....	6	16	2	0
Bradley Fertilizer Co. branch.....	14	41	1	0
Clark's Cove Fertilizer Co. branch....	3	9	0	0
Cleveland Dryer Co. branch.....	3	9	0	0
Crocker Fert. and Chem. Co. branch..	4	12	1	0
Cumberland Bone Phosphate Co. branch	3	9	0	0
L. B. Darling Co. branch.....	2	6	0	0
East India Chemical Co. branch.....	3	9	0	0
Great Eastern Fertilizer Co. branch...	4	12	2	1
Pacific Guano Co. branch.....	3	9	2	0
Quinnpiac Co. branch	4	12	0	0
Read Fertilizer Co. branch.....	7	20	1	0
Henry F. Tucker Co. branch.....	3	9	0	0
Williams & Clark Fertilizer Co. branch.	7	21	3	0
American Agricultural Chem. Co.—Total	66	194	12	1
Armour Fertilizer Works.....	6	16	0	0
Bowker Fertilizer Co.	17	49	2	0
J. F. Bromley	7	20	2	0
Buffalo Fertilizer Co.	7	19	1	0
Burlington Rendering Co.	4	12	0	0
Coe-Mortimer Co.	7	20	0	0
Essex Fertilizer Co.	6	18	1	0
Hubbard Fertilizer Co. of Baltimore City.	1	3	1	0
Listers Agricultural Chemical Works....	9	26	2	0
National Fertilizer Co.	6	18	4	2
New England Fertilizer Co.....	7	21	0	0
Parmenter and Polsey Fertilizer Co....	4	12	0	0
Reading Bone Fertilizer Co.	4	12	2	0
Rogers and Hubbard Co.	8	24	0	0
F. S. Royster Guano Co.	3	9	1	0
J. W. Sanborn	3	9	0	0
Sanderson Fertilizer and Chemical Co...	4	12	0	0
Swift's Lowell Fertilizer Co.....	13	39	0	0
Total.....	182	533	28	3

The range of composition and the closeness with which guaranties are met are shown in the first table on the next page. The condition of affairs it discloses, a close hugging of the guaranties, has obtained for years, as appears in the second table, which shows the excess of the average analysis over the

average guaranty for five years. The manufacturers naturally do not mean to place more plant food than is absolutely necessary in their goods, which carry on the average rather less than ten percent excess over the minimum guaranty. Maximum guaranties, of course, are quite meaningless.

GUARANTIES, ANALYSES, SELLING PRICES AND VALUATIONS

	PERCENT GUARANTIED			PERCENT FOUND			Excess of average analysis over guaranty
	Lowest	Highest	Average	Lowest	Highest	Average	
Nitrogen	0.8	*8.5	†2.14	0.88	8.88	†2.35	0.21
Total phosphoric acid....	5.	16	8.64	5.90	15.04	9.66	1.02
Available phosphoric acid. 4.	11	7.62	4.12	11.30	7.91	0.29	
Potash	1.	12	5.06	1.32	12.20	5.55	0.47
Selling price	\$20	\$59	\$32.11				
Valuation	\$10.45	\$42.88	\$18.87	\$11.21	\$44.20	\$20.07	\$1.20

*No nitrogen in 13 brands.

†Non-nitrogenous goods omitted; if included, average drops 0.14 percent in guaranties and 0.17 percent in actualities.

FIVE YEARS' COMPARISON OF THE EXCESS OF ANALYSES OVER GUARANTIES

	1908	1909	1910	1911	1912	Average for 5 years
Nitrogen	0.18	0.22	0.29	0.20	0.21	0.22
Total phosphoric acid	1.24	1.39	0.83	1.16	1.02	1.13
Available phosphoric acid	0.50	0.59	0.80	0.73	0.29	0.59
Potash	0.33	0.33	0.33	0.26	0.47	0.34
Valuation	\$1.69	\$1.86	\$1.46	\$1.82	\$1.20	\$1.61

While the above statement shows that the goods compare well on the average with the claims made for them, the tables on pages 292 to 307, as well as the statements on pages 254 to 255, betray the fact that within this average lie concealed a few small deficiencies. It is but scant satisfaction to the buyer of a brand in which the amount of plant food guaranteed is not furnished to know that the "average" is good. It is for him to exercise

care and to avoid buying such goods. Yet it should be said that this year no *seriously* faulty fertilizers, so far as guaranty maintenance is concerned, were found. Some years, however, very deficient goods have been offered.

(b) COMPARATIVE VALUES OF FERTILIZERS OF 1911 AND 1912.

Of the 196 brands of commercial fertilizers which were sampled by the Station during 1911 and 1912, 152 have been selected for the purpose of instituting a comparison of the characters of the goods sold under these brand names in each of the two years. Only those brands have been chosen which have been sampled both years. The comparison shows identical nitrogen contents, a third of one percent less available phosphoric acid, and a quarter of one percent more potash together with a fifth of one percent more insoluble phosphoric acid. These pluses and minuses almost exactly offset each other, so that the net result is an average valuation which is practically identical one year as compared with the other.

AVERAGE COMPOSITION OF FERTILIZERS IN 1911 AND 1912

Name of Ingredient	1911		1912	
	Pounds in a hundred	Valuation at 1912 prices	Pounds in a hundred	Valuation at 1912 prices
Nitrogen *	2.06	\$7.31	2.06	\$7.31
Soluble phosphoric acid	5.69	5.12	5.08	4.57
Reverted phosphoric acid	2.62	2.10	2.91	2.33
Insoluble phosphoric acid	1.57	0.63	1.77	0.70
Total phosphoric acid	9.88	...	9.76	...
Available phosphoric acid	8.31	...	7.99	...
Potash *	4.97	4.22	5.21	4.43
		\$19.38		\$19.34

*Nitrogen calculated as half mineral, half organic; potash calculated as muriate.

(c) COMPARATIVE VALUE OF FERTILIZERS FROM 1895 TO 1912.

The next table shows the average composition of the fertilizers as analyzed during the past 18 years. Every brand tested each year is included in the comparison, each one being given equal value. It is well understood that this is not strictly a correct method of calculation, but it is the best which can be done in the absence of data showing the consumption of individual brands. Inasmuch as high grade goods in the past sold slowly, and, unfortunately, low grade brands as a rule readily, the actual average as used is probably somewhat lower than that shown in the table. Yet the evidence in hand indicates a lessened usage of low and a larger usage of medium and high grades.

It ought to be remarked at this point that neither this table, nor the table which immediately precedes it, nor the discussion of this matter, should be construed too literally, for the reasons cited as to the usage of the several brands. Some attempt was made in 1904 to estimate the relative usage of the different grades, but without much success. No data is available that is trustworthy, while if one appeals to the individual judgment of those who are in closest touch with the trade, the inevitable personal equation enters to a large extent. The result of such an inquiry therefore seems so largely a matter of guesswork as to be hardly worth recording. The writer's judgment would place the average goods as actually used at 1.90 to 2.00 percent nitrogen, 8.50 percent available phosphoric acid, and 3.50 to 3.75 percent potash. The relatively larger usage of the low and medium grades and smaller usage of the higher grades which doubtless obtains, tends to lower the general average. But there is evidence tending to show yearly an increase in the usage of the higher grades, a tendency which on the whole is to be encouraged.

The average commercial fertilizer sold in Vermont in 1912 contains 0.10 percent more nitrogen, 0.34 percent less available phosphoric acid and nearly a percent more potash than the average sold of late years.

AVERAGE COMPOSITION OF FERTILIZERS SOLD IN VERMONT FROM 1895 TO 1912¹

Year	Number of brands	Nitrogen	PHOSPHORIC ACID					Potash
			Soluble	Reverted	Insoluble	Total	Available	
1895	92	2.22	5.84	2.56	2.23	10.63	8.40	3.46
1896	110	2.22	5.36	3.44	2.23	11.03	8.80	3.66
1897	134	2.12	5.34	3.68	2.23	11.25	9.02	3.43
1898	126	2.21	5.51	3.32	2.08	10.91	8.83	3.81
1899	137	2.06	5.08	3.32	2.26	10.66	8.40	4.10
1900	132	2.08	5.29	3.26	2.58	11.13	8.55	3.80
1901	134	2.08	5.34	3.23	2.41	10.98	8.57	4.33
1902	136	2.22	5.56	3.06	2.39	11.01	8.62	4.21
1903	111	2.02	5.13	3.42	2.50	11.05	8.55	3.97
1904	118	1.98	5.20	3.19	2.38	10.77	8.39	3.95
1905	130	2.03	4.63	3.63	2.63	10.89	8.26	4.18
1906	130	2.09	4.70	3.65	2.63	10.98	8.35	4.37
1907	129	2.16	4.40	3.60	2.40	10.40	8.00	4.65
1908	130	2.05	4.64	3.50	2.29	10.43	8.14	4.58
1909	133	2.08	5.25	3.07	2.21	10.53	8.32	4.70
1910	152	2.12	5.50	2.86	1.53	9.89	8.36	4.99
1911	157	2.06	5.69	2.60	1.56	9.85	8.29	4.94
1912	182	2.19	4.99	2.92	1.75	9.66	7.91	5.55

AVERAGE COST OF FERTILIZERS SOLD IN VERMONT FROM 1895 TO 1912¹

Year	Number of brands	Average ton selling price	Valuation each year's trade values	Selling price exceeds valuation	Selling price exceeds valuation, %	Value of plant food rec'd for a dollar	Valuation 1912 trade values
1895	92	\$30.90	\$21.28	\$ 9.62	45	69 cts.	\$19.03
1896	110	30.90	19.73	11.17	57	64 "	19.47
1897	134	29.19	19.47	9.72	50	67 "	19.11
1898	126	29.04	17.86	11.18	63	61 "	19.49
1899	137	28.75	17.39	11.36	65	60 "	18.83
1900	132	28.73	18.08	10.65	59	63 "	19.01
1901	134	28.75	19.44	9.31	48	68 "	19.42
1902	136	28.23	20.18	8.05	40	71 "	19.88
1903	111	28.25	18.59	9.66	52	66 "	18.91
1904	118	29.00	18.47	10.53	57	64 "	18.58
1905	130	29.62	19.04	10.58	56	64 "	18.88
1906	130	29.52	19.38	10.14	52	66 "	19.34
1907	129	30.57	21.21	9.36	45	69 "	19.42
1908	130	31.24	20.75	10.49	51	66 "	19.07
1909	133	31.43	18.84	12.59	67	60 "	19.45
1910	152	31.45	20.57	10.88	53	65 "	19.62
1911	157	31.41	19.53	11.88	61	62 "	19.33
1912	182	32.03	20.09	11.94	59	63 "	20.02

¹See statement as to average midway down opposite page.

The increase in the average of the past seven years as compared with those of previous years is due to the high grade of certain goods sold for the first time in 1905, and to the entry in each of several years since of a number of relatively high grade goods. The profound change this year is due to the entry of many new goods. There were 25 more brands sold this year than were offered last year and 50 more than in 1909. Many of these are high grades. This change is doubtless more apparent than real for the newcomers inevitably are not at the outset as widely sold as are the old-timers. A survey of the table on the preceding page indicates that there has been on the whole an up-grading in the last 20 years in the character of the goods used by Vermont farmers. Indeed there seem to be three periods of four, six and seven years respectively, wherein there are to be found somewhat wide variations in the plant food contents of the average goods, particularly in phosphoric acid and potash. The current year, moreover, appears to be the initial year of a new era and to stand by itself. All this is displayed in the following table:

1895-98.....	nitrogen 2.19, available phosphoric acid 8.75, potash 3.60
1899-04.....	nitrogen 2.07, available phosphoric acid 8.51, potash 4.06
1905-11.....	nitrogen 2.08, available phosphoric acid 8.25, potash 4.63
1912.....	nitrogen 2.19, available phosphoric acid 7.91, potash 5.55

The average grade goods are better today than hitherto; but that is not saying that there are not many inferior ones on the market.

At what prices did the sundry forms of available plant food sell in the average mixed fertilizer of these years? These data are afforded by the table shown on the opposite page, from which it is evident that the tendency of late years has been towards increased selling prices. This is particularly true of medium and of high grade goods.

COST OF PLANT FOOD IN THE AVERAGE MIXED FERTILIZER, 1895 TO 1912

Year	Number of brands analyzed	Cost of one pound of organic nitrogen	Cost of one pound of available phosphoric acid	Cost of one pound of potash (as muriate)
1895.....	92	23.9 cts.	8.7 cts.	6.5 cts.
1896.....	110	22.0 "	8.6 "	7.1 "
1897.....	134	21.0 "	8.3 "	6.8 "
1898.....	126	22.8 "	7.3 "	6.9 "
1899.....	137	23.1 "	7.4 "	7.0 "
1900.....	132	24.6 "	7.1 "	6.7 "
1901.....	134	23.7 "	7.4 "	6.3 "
1902.....	136	23.1 "	7.0 "	6.0 "
1903.....	111	25.9 "	6.8 "	6.5 "
1904.....	118	27.5 "	6.9 "	6.7 "
1905.....	130	28.9 "	6.8 "	6.6 "
1906.....	130	28.3 "	6.6 "	6.4 "
1907.....	129	29.6 "	6.9 "	6.1 "
1908.....	130	30.6 "	7.1 "	6.3 "
1909.....	133	31.7 "	6.3 "	7.1 "
1910.....	152	30.6 "	6.6 "	6.5 "
1911.....	157	32.2 "	7.0 "	6.8 "
1912.....	182	30.2 "	6.9 "	6.8 "

2. AS TO QUALITY OF PLANT FOOD.

(a) SOURCES OF PLANT FOOD IN LICENSED FERTILIZERS.

The table on page 258 as well as those of pages 292 to 307 show wide ranges in composition, amounts of nitrogen varying from 0.88 to 8.88 percent., of available phosphoric acid from 4.12 to 11.30 percent., and of potash from 1.32 to 12.20 percent. These figures alone, however, do not tell the whole story as to the character of the ingredients used, a matter of quite as much importance as their amounts. A further scrutiny into the details of the sundry analyses throws some light on the sources whence the plant food purveyed in the various brands is derived.

NITROGEN.

In all but 3 of the 169 brands carrying nitrogen, more or less of the mineral forms thereof was found to be present. Some of

the 19 manufacturers selling in Vermont have in the past habitually used nitrate of soda or sulphate of ammonia as a means of supplying nitrogen; others have only begun the use of mineral forms of nitrogen within the past few years. Doubtless the fact that mineral nitrogen is far cheaper today than is organic nitrogen explains its present freer usage. Time was, not long ago, when the ratio of mineral to organic nitrogen was much less than it is today in the goods sold in Vermont, and when a large share of the goods contained neither nitrate nor ammonia salts. The amounts found in this year's goods vary from 0.11 to 8.13 percent., averaging 1.06 percent. or 48 percent. of the total nitrogen present in the brands carrying this ingredient. In 23 of these brands the amounts of mineral nitrogen present were very small, but in the residue the amounts were readily measurable. Under certain circumstances and for certain purposes mineral nitrogen, particularly in the nitrate form, is to be preferred agriculturally to organic nitrogen. Under other circumstances it is not as much to be desired. It is more readily available but is more easily lost by leaching (see pages 89 to 90 of bulletin 99). Speaking broadly, however, the presence of mineral nitrogen in commercial fertilizers is to be favored for most of the purposes for which such goods are used in Vermont.

All the brands which carry nitrogen contain more or less organic nitrogen, derived doubtless as a rule from standard animal and vegetable ammoniates, such as dried blood, meat meal, fish scrap, tankage, etc. Probably tankage is at present its main source in a large proportion of the brands.

For the second time this Station, joining with its sister stations in the North Atlantic states, prints in its table of analyses tabulated data as to the character of the organic nitrogen used in the various brands offered for sale, with a view of indicating its serviceability in crop growth. This Station for more than a dozen years has thus "kept tab" on the several fertilizers offered for sale. It has formed an opinion in many cases of the character of the organic nitrogen used therein. It has not

hesitated by correspondence and by personal interview to question the character of the organic nitrogen used in certain brands, and has in times past not infrequently found its queries to be justified by the facts, either directly acknowledged, or at least not gainsaid, by the manufacturers. Its long experience with the alkaline permanganate method of determining organic nitrogen availability, the long series of analytical results accumulated in its files during the past dozen years, the work done by other stations in this section of the country using the same method, have served to give it confidence in the essential accuracy of its findings. But it has not prior to 1911 deemed itself justified in publishing the results as applied to the separate brands of goods as found on sale.

Beginning in 1911, the nitrogen content of all commercial fertilizers as sold in the North Atlantic states, (other than Pennsylvania) is now to be stated, if deemed practicable by the official in charge of the control, in the following terms:

1. Nitrogen in nitrates.
2. Nitrogen in ammonia salts.
3. Water soluble organic nitrogen.
4. Active water insoluble organic nitrogen.
5. Inactive water insoluble organic nitrogen.
6. Total nitrogen found.
7. Total nitrogen guaranteed.

In order that the reader may clearly understand just what is meant by this phraseology the following explanatory notes are offered:

1. *Nitrogen in nitrates.* The data in this column indicates the percentage of nitrogen found to be present which is derived from nitrate of soda, a mineral form of nitrogen which is soluble in water and immediately available to plant growth.

2. *Nitrogen in ammonia salts.* The data in this column indicates the percentage of nitrogen derived from sulphate of ammonia, a gas-house or coke-oven by-product of high grade.¹

¹The nitrogen derived from calcium cyanamid would appear either here or as "water soluble organic nitrogen," or both, according to circumstances.

It is a mineral form of nitrogen which is soluble in water and readily available to plant growth.

3. *Water soluble organic nitrogen.* The data in this column indicates the percentage of nitrogen derived from organic sources which is soluble in water.¹ The presumption is that most organic nitrogen soluble in water is likely on that account to be relatively available to plant growth.

4. *Active water insoluble organic nitrogen.* The data in this column indicates the percentage of such organic nitrogen as is not soluble in water, but, notwithstanding, is deemed to be relatively available to plant growth, this judgment being based upon the relative readiness with which it has been acted upon by the chemicals used in the modified alkaline permanganate method as well as upon extensive vegetation trials.

5. *Inactive water insoluble organic nitrogen.* The data in this column shows the percentage of the water insoluble organic nitrogen that has not been acted upon by the chemicals used in the modified alkaline permanganate process. It is considered less available to plant growth than are those forms which are scheduled under the other heads.

In order that the significance of the data in the analytical tables may be the more clearly understood, the sets of hypothetical figures shown below are submitted:

Quality of organic nitrogen	Nitrogen in nitrates	Nitrogen in ammonia salts	Water soluble organic nitrogen	Active water insoluble organic nitrogen	Inactive water insoluble organic nitrogen	Total nitrogen found
A. Good,	0.11	0.21	0.27	0.53	0.25	1.37
B. Good,	0.57	1.40	0.27	0.69	0.32	3.25
C. Somewhat questionable,	0.10	0.70	0.20	0.35	0.35	1.70
D. Inferior,	1.00	0.10	0.15	0.25	0.45	1.95
E. Inferior,	0.80	1.10	0.10	0.20	0.30	2.50

¹See footnote page 265.

Why are A and B good? Why are D and E inferior? Why should one list A as "good" when it contains only about half as much total nitrogen as does E which is listed as inferior? Would on this account A be a better purchase than E? Of course in the purchase of commercial fertilizers a number of different considerations have to be taken into account. However in this discussion of organic nitrogen availability just one thing is being kept in mind, *the quality*, not the quantity, of the organic nitrogen used. It is a question of character rather than of amount; of the nature of the organic nitrogen used rather than of the total nitrogen content. The state law very properly forbids the use of inferior forms of organic nitrogen unless their use is declared on each package. The fact moreover that the mineral nitrogen contents of D and E are large, and that, of course, such nitrogens are readily available, has no bearing upon the particular matter now under consideration. In other words, that is not the point. The organic nitrogens used in the manufacture of D and E are relatively inferior. One should note concerning the hypothetical figures:

A. That only 0.25 percent of the 1.05 percent of total organic nitrogen is classed as being relatively inactive and only 0.25 percent of the 0.78 percent of the water insoluble organic nitrogen is thus classified.

B. That only 0.32 percent of the 1.28 percent and only 0.32 percent of 1.01 percent of water insoluble organic nitrogen are thus classified.

C. That 0.35 percent of 0.90 percent and 0.35 percent of 0.70 percent are thus classified.

D. That 0.45 percent of 0.85 percent and 0.45 percent of 0.70 percent are thus classified.

E. That 0.30 percent of 0.60 percent and 0.30 percent of 0.50 percent are thus classified.

Comparing these figures on the hundred percent basis one finds in the better goods 24 and 25 percents of the nitrogen classified as relatively inactive; in the poorer goods, 49 and 50 percents;

and of the water insoluble nitrogen in the better goods 31 and 32 percents are classified as inactive; in the poorer goods, 65 and 60 percents. It is the relativity of the figures rather than the absolute figures which determines matters.

Now as to the specific cases developed in this year's inspection. There appears to be no reason to cavil at the results afforded by the analyses of the goods sold by sixteen of the nineteen companies licensed in Vermont, although the goods sold by two companies, as a class, do not seem to make of the best medium grade ammoniates. Attention is called however to the relatively high inactive water insoluble organic nitrogen contents as compared with the water insoluble organic nitrogen and active water insoluble organic nitrogen contents of the following brands. There seems reason in each case to question the quality of the organic nitrogen used.

Reading Bone Fertilizer Co., Reading, Penn.

L 9. Special Potato and Tobacco.

L 10. Never Fail Crop Grower.

F. S. Royster Guano Co., Baltimore, Md.

E 11. Imperial Formula.

Correspondence with these companies developed the following situation:

The Reading Bone Fertilizer Company denies the assertion as to inferiority of the organic nitrogen used in the brands in question; "guaranties the goods to be absolutely free from leather meal and hair refuse or any other inferior ammoniate"; and asks that the Station state that "the organic nitrogen was derived from bone and tankage." The Station regrets to be unable to make such a statement, unless it is permitted to put the word "garbage" before the word "tankage." It should be clearly understood, however, that the Station does not gainsay the fact that tankage, properly so-called, may have been used, but it asserts that some other inferior form of ammoniate has also been in part employed.

The F. S. Royster Guano Co. claims touching the organic nitrogen used in the one brand which is in question that it "only guaranties 0.82 percent of nitrogen in these goods"; that "any

excess above guaranty is not charged for"; that "the price to the trade is based on the guaranty of 0.82 percent of nitrogen"; that "the station analysis shows it to contain 0.77 percent of available nitrogen, so that only 0.05 percent of the nitrogen guaranteed was found unavailable"; that "the excess of 0.22 percent of nitrogen more than guaranteed was all surplusage"; and that "with this showing there should be nothing said prejudicial to these goods." The Company further states "had it known the materials used (a certain amount of garbage tankage and mill dust to give the goods bulkiness) were not permitted without special notice, it would never have used them."

The Public Statutes, so far as they relate to the use of inferior ammoniates in commercial fertilizers, read as follows:

"SEC. 4980. *Prohibited materials in composition.* No person shall sell or expose for sale leather or its products, hair, wool waste, garbage tankage or inert nitrogenous material, as a fertilizer or ingredient thereof, unless an explicit printed statement of the fact is conspicuously affixed to each package of such fertilizer, and accompanies each such parcel or lot of the same."

The use of garbage tankage is not illegal, but being used its presence must be declared upon the package. That the full nitrogen guaranty is furnished in approved forms, and that garbage tankage is to some extent serviceable, do not abrogate this explicit requirement. Strictly speaking, the legal maxim holds that "ignorance of the law excuses no one." In view, however, of the fact that the F. S. Royster Co., sells its goods this year in Vermont for the first time, and that consequently it did not receive advance notice in 1910, as did the companies then selling in Vermont, as to the intended use of a method for discriminating between organic nitrogens and the publication of the results obtained; and, furthermore, in view of the fact that the inclusion of garbage tankage among materials inhibited by fertilizer control laws is not common, the writer is led to believe that little stress need be laid upon this matter this year, particularly since the material which was used was certainly not detrimental and the

guaranty is nearly made good with nitrogen from sources which seem above question.

Last year, the first in which the present system of publication of organic nitrogen availabilities was inaugurated, four companies and ten brands were specially mentioned as using and carrying relatively inert nitrogen. These companies still sell in Vermont and eight of the ten brands are offered this year. No criticism can be urged this year as to the quality of the nitrogen purveyed by these companies in these or other brands, save in one brand on the border line. In no year previous to the present one since this Station has been using the alkaline permanganate method has there been so little reason for questioning the character of the organic nitrogen sold to Vermont farmers; and in view of the fact that the three brands named above are new comers and doubtless have been thus far sold in but a small way, it is safe to say that this year's trade is in this respect all that could be desired, a most satisfactory outcome.

PHOSPHORIC ACID.

Some companies furnish more total phosphoric acid in available form than do others; some, more of the water-soluble relative to the citrate-soluble or reverted than do others. Water-soluble phosphoric acid cannot be other than of the best grade and is to be preferred to that not thus soluble. Citrate soluble phosphoric acid, while often, and perhaps usually, quite as good agriculturally as that which is soluble in water, may be of distinctly lower grade (agriculturally) if certain classes of phosphatic crude stock, such, for example, as ignited alumina phosphate, are used. Low soluble and high reverted phosphoric acid contents do not of necessity mean that the available phosphoric acid is not as valuable as when the conditions are reversed, but that the likelihood of this being true is lessened.

The proportions of the total phosphoric acid found in the various brands to be in available forms varied from 49 percent to 97 percent. The proportions of available phosphoric acid

found to be in a water-soluble form varied from almost nil to 93 percent. Grouped according to their manufacture it was found that extremes for available in total were 67 and 91 percents, for water-soluble in available 34 and 74 percents. In other words the average goods made by one firm carried 91 percent of the total phosphoric acid in available form, while those made by another firm furnished but 67 percent in that shape, the remainder ranging between. Similarly, on the average 74 percent of the available phosphoric acid furnished by one manufacturer was soluble in water, while only 34 percent was thus soluble in the average goods of another firm. The low availability seems to be due in some cases to the use of considerable quantities of incompletely dissolved bone or of bone meal. Whether in other cases it is due to this cause, to imperfectly cut phosphate rock, to the age of the goods, to the use of agriculturally inferior forms of phosphoric acid, or to other causes, does not always appear.

POTASH

This ingredient is sold in mixed goods in the form of muriate, sulphate, kainit, or, possibly very rarely, nitrate. The direct or inferential claim has been made in the past for a large proportion of the brands selling in Vermont that sulphate of potash had been used in their manufacture. Last year, for instance, this claim was made for two-thirds of the entire number. It is made this year for only a fourth of the total number. This allegation is usually merely a subterfuge, it is intentionally misleading, and has many times been shown to be unwarranted by the facts. It is doubtless not illegal for a manufacturer to indicate an equivalence, since such an expression is not strictly speaking a guaranty, but simply a portion of that surplusage with which manufacturers have thus far been prone to bedeck the fertilizer sacks. Happily a movement is now in progress looking towards the simplification of the guaranty statement, and the elimination of the multitudinous figures which serve

to befog the buyer. One of the first manifestations of this tendency is shown in the marked change as regards this inferential potash claim. Twelve of the 19 companies selling in Vermont now make no claims as to sulphate equivalence and tell no "near fibs" touching the matter. Seven of these 12 companies (Armour Fertilizer Works, J. F. Bromley, Buffalo Fertilizer Co., Burlington Rendering Co., Coe-Mortimer Co., Parmenter & Polsey Fertilizer Co., Rogers and Hubbard Co.) have been "lily white" in this respect in former years; four companies (Hubbard Fertilizer Co., National Fertilizer Co., J. W. Sanborn, and F. S. Royster Guano Co.) sell in Vermont this year for the first time; and one company (Listers Agricultural Chemical Works), a consistent sinner in the past in this respect, appears to have seen the error of its ways and has omitted this year the equivalence statement. Two other companies (Bowker Fertilizer Co. and American Agricultural Chemical Co.) which have claimed sulphate in the past are in process of joining the ranks of the progressives. The former makes no claim as to the use of sulphate in 13 of its 17 brands, even for one in which as a matter of fact sulphate was used, but it does claim it on all shipments of one brand and for three others in part of the shipments. The latter named company has dropped the claim for 39 of its 66 brands. The Essex Company now claims sulphate in but 1 of its 6 brands. The Reading Bone Fertilizer Co., a new comer, claims it for all its brands; the New England Fertilizer Co., claims it for 6 of their 7 brands; the Lowell Fertilizer Co. for 9 of their 14 brands; the Sanderson Fertilizer and Chemical Co. for 3 of their 4 brands. These companies may be said to be reactionary in this respect. Patrick Henry inveighed against those who in revolutionary times cried, "Peace, peace, when there is no peace." These companies claim inferentially, sulphate; sulphate, when there is no sulphate, save in a single case. The reform instituted by their competitors is respectfully recommended to the conservatives.

As a matter of fact, sulphate was found to be used in part or whole in only 8 brands, namely:

American Agricultural Chemical Co.'s Grass and Lawn Topdressing.

American Agricultural Chemical Co.'s Bradley's Complete Manure for Potatoes and Vegetables.

Bowker Fertilizer Co.'s Stockbridge Seeding Down Fertilizer.

J. F. Bromley's Potato Special.

New England Fertilizer Co.'s Superphosphate for all Crops.

Rogers and Hubbard Co.'s Soluble Potato Manure.

Rogers and Hubbard Co.'s Soluble Tobacco Manure.

J. W. Sanborn's Manure for Potatoes and Corn.

Oddly enough the sulphate equivalence which would have been entirely justified in these cases is indicated for but one of these brands; in other words, the inferential claim is made for 51 brands, being justified in one case and not justified in 50 cases. Per contra, it might have been claimed in 8 cases, but as a matter of fact was claimed in but a single case. Practically sulphate of potash does not enter into the Vermont fertilizer trade. The few brands in which it is present do not apparently enjoy large sales. It is evident that in the near future the misleading claim will be relegated to the scrap heap. It is hoped that this is but the initial step towards the adoption by the trade at large of a simplified guaranty statement which will furnish minimum figures only. Wherever the asterisk (*) or dagger (†) appear in connection with the potash figures in the columns thus headed on pages 292 to 307, sulphate of potash was found to be present. Where these signs do not appear, the potash was derived from muriate or kainit, or else a sufficiency of chlorin was present in other combinations to mask the presence of sulphate and entirely to nullify its good effects, if any.

IV. THE RELATION BETWEEN SELLING PRICE AND VALUATION.

The relationship of the selling price to the valuation of fertilizers of different grades has been elaborated annually for more than 15 years. It has been customary of late to approach the matter from two directions, to make two classifications, basing one on *cost* and the other on *value*. Three groups, somewhat arbitrarily formed, designated "low priced," "medium priced" and "high priced," furnish the means of comparing the cost, while as many groups termed "low grade," "medium grade" and "high grade" serve the purposes in the study of relative values.

When grouped according to selling prices the item of *cost* is emphasized; when the valuations govern the sub-divisions, the stress is laid upon the *worth* of the material. The selling price may or may not bear an essentially just relation to the plant food content of the fertilizer. The valuation, however, is a more exact measure. Since both cost and worth are important factors, and since some may grasp the facts readily when presented from one viewpoint while others see the situation better when looked at from the other side, it has been deemed best to present the results of both methods of comparison. The general outcome is much the same, either way the proposition is figured.

I. FROM THE STANDPOINT OF COST.

The brands may be classified as to selling price as follows:

	Number of brands	Percent- age of total	Average selling price
Low priced, selling at \$28.50 or below....	57	29	\$26.07
Medium priced, selling from \$29 to \$33....	67	37	30.43
High priced, selling for \$33.50 or more..	62	34	39.08

The average, largest and smallest values of plant food offered in the groups of brands appear below. The figures show the values of plant food bought for a dollar in the average goods

of each grade, including the greatest as well as the least value obtained in any brand in each class.

VALUE OF PLANT FOOD BOUGHT FOR A DOLLAR

	Average	Smallest	Largest
Low priced	\$0.55	\$0.45	\$0.75
Medium priced	0.59	0.45	0.80
High priced	0.69	0.52	0.86

It is interesting to note the number of brands in each group which furnish less than 55 cents' worth of plant food¹ for a dollar, as well as the number which afforded more than 65 cents' worth for the same sum:

Low priced:	Less than 55c. worth, 30; more than 65c. worth, 3
Medium priced:	Less than 55c. worth, 17; more than 65c. worth, 9
High priced:	Less than 55c. worth, 1; more than 65c. worth, 48

The comparisons can be shown graphically. The relative length of the following lines show the average money value in plant food at retail seaboard prices bought for a dollar at Vermont delivery points in brands selling for \$28.50 or less, (low priced), from \$29 to \$33 (medium priced), and for \$33.50 and above (high priced):

Low priced: 55 cents for a dollar spent.

Medium priced: 59 cents for a dollar spent.

High priced: 69 cents for a dollar spent.

The following lines show the proportion of the total number of brands in each group containing 55 cents or less worth of plant food for each dollar paid for the fertilizer:

Low priced: 57%.

Medium priced: 26%.

High priced: 2%.

¹The phrase "55 cents' worth of plant food" should be construed to mean an amount of plant food which, if bought for cash at retail at the seaboard, would have cost 55 cents in standard, unmixed, raw materials.

The final set of lines show the proportion of the total number of brands in each group containing 65 cents or more worth of plant food for each dollar paid for the fertilizer:

Low priced: 6%.

Medium priced: 14%.

High priced: 78%.

If lines and figures are put into words, it will be seen that:

1. The same amounts of plant food which cost a dollar in the average low priced brands (\$28.50 and below) might have been bought in the unmixed state at retail and at the seaboard for 55 cents; in the average medium priced goods (\$29 to \$33), for 59 cents; and in the average high priced goods (\$33.50 and upwards), for 69 cents. Extremes of values were 86 and 45 cents. In more than one-fourth of the brands the sums charged for manufacture, transportation, sale, etc., comprised more than 45 percent of the retail cost, thus leaving less than 55 percent to pay for the plant food; while in eleven brands these charges equalled or exceeded the seaboard value of the unmixed plant food.

2. In nearly three-fifths of the total number of low priced brands the charges for mixing, sale, etc., aggregated at least 45 percent of the selling price, while in only one in four of the number of medium priced brands and in but one of the high cost goods were the charges thus large.

3. Three-fourths of the total number of high class goods contained an equivalent of 65 cents or more worth of plant food at retail seaboard prices. But one in seven of the medium grade and but one in sixteen low grade goods contained so high an equivalent.

These things are naturally so, inevitably so. There are good and sufficient reasons for this showing, which may be condensed in a nutshell as follows: It costs as much to mix, to store, to regrind, to bag, to ship, to freight, to sell, to collect for sales, etc., a ton carrying 1,200 pounds of genuine fertilizer

and 800 pounds of mere filler (diluent) as it does to mix, store, regrind, bag, freight, sell, etc., etc., a ton of goods that contains a full 2,000 pounds of undiluted fertilizing crude stock. Hence it follows that the buyer of low grade goods must pay for all this useless handling of the nearly or quite worthless filler. It is an old story, reiterated year after year, but it is one which needs to be told as long as material usage of low grade brands obtains.

2. FROM THE STANDPOINT OF VALUE.

Let us now turn the matter about and study it from the standpoint of *worth*. The figures and proportions naturally differ from those just presented. The brands may be classified as to valuation as follows:

	Number of brands	Percent- age of total	Average valuation
Low grade, valuing at \$15.50 or less.....	49	27	\$13.68
Medium grade, valuing at \$15.51 to \$22..	68	38	18.27
High grade, valuing at \$22.01 and upwards	63	35	27.03

The composition, selling price and valuation of the average brand of each group appears in the following table:

	Nitrogen	Available phosphoric acid	Potash	Total plant food, pounds	Average selling price	Average valuation	Selling price exceeds valuation by
Low grade ...	0.95	8.16	2.97	12.1	\$26.62	\$13.68	\$12.94
Medium grade..	1.98	8.17	4.20	14.3	29.63	18.27	11.36
High grade...	3.40	7.50	9.08	20.0	38.90	27.03	11.87

A survey of this table indicates that:

1. The proportion of nitrogen increases in regular graduations from group to group; that of phosphoric acid drops two-thirds of one percent from the lower and medium to the high

grade goods; while the potash increases one and one-fourth percent in the medium and nearly six percent in the high grade brands, as compared with the lower ones.

2. The low grade goods carry nearly nine times as much phosphoric acid as they do of nitrogen and nearly three times as much phosphoric acid as they do of potash. These ratios become four and two in the medium grade. In the high grade fertilizers there is only a little more than twice as much phosphoric acid as nitrogen, and one and one-half percent more potash than phosphoric acid. The latter grade more closely resembles the proportions commonly present in the crops ordinarily grown than do either of the other grades..

3. The medium grade goods for one-ninth advance in price over the cost of the low grade brands offers nearly one-fifth more plant food and one-third more commercial value.

4. The high grade fertilizers for less than one-half advance in price over the cost of the low class goods furnish two-thirds more plant food and almost double the commercial value.

5. The higher the grade the less the margin between cost and worth, both actually and relatively. In buying the average low grade brand, one paid this year \$12.94 for service of one sort or another (factory and office charges, freight, selling expenses, etc.) incurred in the delivery of \$13.73 worth of plant food; when medium grade goods were bought, \$11.36 service charges placed \$18.30 worth of plant food in the buyer's hands; and when high grade goods are bought, \$11.87 service charges placed \$27.03 worth of plant food in the buyer's hands. Or, phrasing the matter another way,

THE COST OF PLACING A DOLLAR'S WORTH OF PLANT FOOD IN THE
FARMER'S HANDS WAS

In low grade goods	94 cents
In medium grade goods	62 cents
In high grade goods	44 cents

It may be worth while now to scan the prices paid for a pound each of nitrogen, of available phosphoric acid and of potash in the several grades. The next table shows this, including the average, lowest and highest costs as well as the retail cash cost of these ingredients in Boston or New York, or, in other words, their "valuations." (See pages 250-251).

COST OF A POUND OF PLANT FOOD IN FERTILIZERS OF VARIOUS GRADES

	MINERAL NITROGEN			ORGANIC NITROGEN			AVAIL. PHOSPHORIC ACID			POTASH		
	Average	Highest	Lowest	Average	Highest	Lowest	Average	Highest	Lowest	Average	Highest	Lowest
Low grade,	32.1	36.8	22.1	36.9	42.4	25.3	8.4	9.7	5.8	8.3	9.5	5.7
Med. grade,	26.7	36.4	20.6	30.8	41.9	23.8	7.0	9.5	5.4	6.9	9.4	5.3
High grade,	23.8	31.7	19.1	27.4	36.5	22.	6.2	8.3	5.0	6.1	8.2	4.9
Retail cost, Boston or New York, 16.5				19			4.33			4.25		

The same lesson enforced in a different way, that cheap fertilizers are the most costly. Some Vermont buyers paid more than forty cents for a pound of nitrogen which they might have bought for nineteen cents laid down at their doors in mixed fertilizers. They paid under similar circumstances eight cents a pound for phosphoric acid and ten cents for potash instead of five cents. They paid almost double prices because they did not give the matter attention, or, perhaps, because they did not believe in "book farming." The thoughtful buyer of high class goods, sold at not overhigh prices, bought plant food at figures not much in advance of valuations plus freight rates.

It ought to be said in this connection that the same brands similarly named, in different localities, as well as the same goods variously named in one locality or, indeed, in one dealer's hands, are sometimes found to sell at different prices, and apparently

without good reason. A few exorbitant charges have been noted. Moreover, purchasers often fail to exercise good judgment in their choices and pay overhigh charges owing to lack of information as to what to buy and how to buy it. That this situation is largely their own fault can justly be claimed, since the State has thrown about this trade safeguards which are lacking with almost every other class of traffic. The yearly fertilizer inspection, the publication of the results of the work, the free distribution of the bulletins, the clear and concise statements as to the brands on sale, the simplicity and directness of the few fundamental facts which are the main guides as to choice and to purchase; all these are ample justification of the statement that, speaking in general terms, he who is dissatisfied with the results attained with fertilizers, so be it weather conditions favor and the seed is good, has himself to thank for it. This dissatisfaction may be due to unwise choice, that is to say the purchase of a goods ill-adapted to a specific purpose; or, it may arise from the realization that one has paid an unreasonably high price in view of the grade of the goods. In either case a repetition of the experience may be avoided by the exercise of a little care as to choice. Particularly in the matter of purchase there often appears to be but little relation between price and plant food content. Thus, for example, goods guaranteed to carry uniform available phosphoric acid contents, but the highly variable nitrogen and potash contents noted below have been found in recent years selling at a uniform price at points where freight rates were not materially unlike:

Nitrogen, 33 lbs.;	potash, 40 lbs.;	nitrogen and potash, 73 lbs.
Nitrogen, 41 lbs.;	potash, 30 lbs.;	nitrogen and potash, 71 lbs.
Nitrogen, 16 lbs.;	potash, 80 lbs.;	nitrogen and potash, 96 lbs.
Nitrogen, 41 lbs.;	potash, 60 lbs.;	nitrogen and potash, 101 lbs.

Frequently two brands of the same make with identical nitrogen and phosphoric acid guaranties but with different potash guaranties (1.5 and 3 percents) are found sold at a flat price.

That is to say a local agent will offer a corn fertilizer at \$30 and a potato phosphate at \$30, each containing equal amounts of nitrogen and phosphoric acid, but the latter twice as much potash as the former. This is no sin; neither is it against the law. But what well-informed buyer would choose the corn goods in preference to the potato brand? Yet doubtless many do.

Identical but differently named goods were sometimes sold by one and the same agent at different prices. Again, two brands with similar nitrogen and phosphoric acid guaranties but different potash figures were sold by the same agent at different prices, the higher price being asked for the lower guaranteed goods.

A few more examples of some of these anomalies observed in recent years may serve to cause some buyers more carefully to scrutinize their purchases.

A Washington County agent offered at identical prices goods made by the same company guaranteed as follows:

Nitrogen	Total phosphoric acid	Available phosphoric acid	Potash
2.47	9	8	4
1.65	9	8	2

The first carried a quarter part more available plant food than the second; but they were offered at the same price. This same dealer charged only three dollars a ton more for goods made by the same manufacturer containing 2.5 percent nitrogen and 10 percent potash. For an advance of 10 percent in price, he furnished almost 60 percent more plant food.

Another agent in the same county offered two low grade goods of the same make, one carrying a percent each more available phosphoric acid and potash and a quarter of a percent more nitrogen, or one-fourth more total plant food than did the other; but both sold at the same price and both were costly purchases, for one furnished only 47 cents' worth and the other only 44 cents' worth of plant food for a dollar.

An Addison County dealer offered at a uniform price corn and potato goods of the same make, the one guaranteed to carry

a third more nitrogen than the other and an equal amount of the other ingredients. Other and similar cases might be cited.

The non-nitrogenous brands, thirteen of which are licensed, being relatively cheap are quite popular and somewhat widely sold. As a class they furnish costly plant food. As sold this year in Vermont they average to offer only 56 cents' worth of plant food for a dollar. When one has ample home supplies of nitrogen, non-nitrogenous goods may prove advisable purchases; but commercially they are usually expensive plant food.

3. AS BETWEEN MANUFACTURERS.

One company averaged to charge 22 cents for placing a dollar's worth of plant food in the buyer's hands. Yet another asked 79 cents for the same service. In the one case a dollar bought 82 cents' worth of plant food, in the other, 56 cents' worth. For half of the brands offered by each of two companies was asked from 80 cents upwards for the laying down of a dollar's worth of plant food at the buyer's depot; or, stating it another way, the buyer of their low priced brands paid from \$1.85 to \$2.22 and received therefor a dollar's worth of plant food. His neighbors paid in some cases as low as \$1.22 for a dollar's worth. Which made the wiser purchase? It is not difficult for anyone to apply this test before purchase. Thus, for example: Selling price, \$30; guaranty, nitrogen 2%; soluble, reverted and insoluble phosphoric acids, 6, 3 and 1%^s; potash 3%. $2 \times 20 \times .19 = 7.80$.¹ $6 \times 20 \times .045 = 5.40$. $3 \times 20 \times .04 = 2.40$. $1 \times 20 \times .02 = 0.40$. $3 \times 20 \times .0425 = 2.55$. $\$7.80 + \$5.40 + \$2.40 + \$0.40 + \$2.25 = \18.55 . $18.55 \div 30 = 62^2$; or $30 \div 18.55 = 1.62^3$. Sixty-two cents' service charge to cover the cost of laying down at the buyer's depot a dollar's worth of plant food; sixty-two cents' worth of plant food received by the buyer for a dollar spent.

¹ I. e., 2% (or 2 pounds per 100) nitrogen, multiplied by the trade value of a pound of nitrogen (19 cents) affords the valuation of the guaranty of nitrogen, \$7.80. The other calculations are similarly made.

² Valuation divided by cost equals worth of plant food per dollar spent.

³ Cost divided by valuation indicates service charge paid for a dollar's worth of plant food bought.

V. OBSERVANCE OF THE FERTILIZER LAW.

LIST OF LICENSED COMMERCIAL FERTILIZERS.

The following companies have paid licenses on the 182 brands specified on this and the next few pages as well as on the 6 brands listed on page 249 no sample of which were drawn. The list also shows the points at which samples were drawn and the laboratory sample numbers, referring to the analyses on pages 292 to 307.

AMERICAN AGRICULTURAL CHEMICAL CO., 2 Rector St.,
New York, N. Y.

H 11 & J 70 Grass and Lawn Topdressing; Brattleboro.

H 16 Special Grass and Garden Mixture; Brattleboro.

M 3 Grass and Oats Fertilizer; St. Albans.

F 3 High Grade Fertilizer with Ten Percent Potash; Groton.

J 7 Northwestern Challenge Crop Grower; Irasburg.

H 16 Special Grass and Garden Mixture; Brattleboro.

(Bradley Fertilizer Co. brands).

M 11 Alkaline Bone with Potash; Waterbury.

H 13 Complete Manure for Potash and Vegetables; Brattleboro.

K 3 Complete Manure for Corn and Grain; Manchester.

A 12 Complete Manure with Ten Percent Potash; Burlington.

K 2 Complete Manure for Topdressing Grass and Grain; Manchester.

A 11 Corn Phosphate; Poultney.

A 13 & P 2 Eclipse Phosphate for all Crops; Poultney.

E 10 Green Mountain Special; Jonesville.

C 12 High Grade Potato and Root Special; Poultney.

C 11 Niagara Phosphate; St. Albans.

C 10 Potato Fertilizer; Bethel.

E 7 Potato Manure; Burlington.

F 4 Vermonter for all Crops; Hardwick.

A 14 and P 1 XL Superphosphate of Lime; St. Albans.

(Clark's Cove Fertilizer Co. brands).

- K 16 *Bay State Fertilizer* G. G.; Brownington.
- F 8 *King Philip Alkaline Guano for all Crops*; Lunenburg.
- K 4 *Potato Fertilizer*; Underhill Center.

(Cleveland Dryer Co. brands).

- K 5 *Fertilizer for all Crops*; Sheldon Junction.
- H 15 *Potato Phosphate*; Windsor.
- H 14 *Superphosphate*; Windsor.

(Crocker Fertilizer and Chemical Co. brands).

- B 12 *Ammoniated Corn Phosphate*; South Royalton.
- G 3 *New Rival Ammoniated Superphosphate*; Underhill.
- B 13 *Potato, Hop and Tobacco Phosphate*; South Royalton.
- B 14 *Special Potato Manure*; South Royalton.

(Cumberland Bone Phosphate Co. brands).

- K 6 *Guano for all Crops*; Waterbury.
- K 15 *Potato Fertilizer*; Cabot.
- K 14 *Superphosphate*; Cabot.

(Darling Fertilizer Co. brands).

- K 7 *Farm Favorite*; Newbury.
- L 1 *General Fertilizer*; Waterford.

(East India Chemical Co. brands).

- J 9 *Complete Potato Manure*; Groton.
- G 12 *Harvest Home Phosphate*; Groton.
- J 8 *Standard UnXID Fertilizer*; Jericho.

(Great Eastern Fertilizer Co. brands).

- J 15 *Garden Special*; East Hardwick.
- B 7 *General Fertilizer*; Bethel.
- B 8 *Northern Corn Special*; Bethel.
- B 9 *Potato Manure*; Bethel.

(Pacific Guano Co. brands).

- F 1 *Nobsque Guano for all Crops*; North Bennington.
- F 2 *Potato Special*; Lyndonville.
- E 1, P 14 and F 23 *Soluble Pacific Guano*; Burlington.

(Quinnipiac Co. brands).

C 9 Climax Phosphate for all Crops; Montpelier.

A 10 Corn Manure; East Poultney.

C 8 Market Garden Manure; Montpelier.

A 9 Potato Phosphate; East Poultney.

(Read Fertilizer Co. brands).

A 7 Farmer's Friend Superphosphate; St. Albans.

A 8 High Grade Farmer's Friend Superphosphate; St. Albans.

J 5 Leader Blood and Bone; Chester.

C 5 and P 22 Potato Manure; St. Albans.

C 6 Practical Potato Special Fertilizer; Swanton.

C 7 Standard Superphosphate; Swanton.

M 7 Sure Catch Fertilizer; Swanton.

(H. F. Tucker Co. brands).

K 1 Imperial Bone Superphosphate for all Crops; Huntington.

F 10 Imperial Bone Superphosphate for Corn; Lunenburg.

F 9 Imperial Bone Superphosphate for Potatoes; Lunenburg.

(Williams & Clark Fertilizer Co. brands).

A 2 Americus Ammoniated Bone Superphosphate; Barre.

E 1 Americus Corn Phosphate; Barre.

H 12 Americus High Grade Special for Potatoes, Roots and Vegetables; Brattleboro.

A 4 Americus Potato Manure; Swanton.

A 3 Potato Phosphate; Montpelier.

A 5 Prolific Crop Producer; Montpelier.

A 6 Royal Bone Phosphate for all Crops; Swanton.

ARMOUR FERTILIZER WORKS, 930-938 Equitable Building, Baltimore, Md.

M 12 Banner Brand; Bennington.

H 1 Bean and Farm Fertilizer; Pownal Center.

J 1 Complete Manure; Bellows Falls.

G 15 and P 8 Fruit and Root Crop Special; Pownal Center.

G 16 High Grade Potato Fertilizer; Pownal Center.

J 16 Trucker Special; Bennington.

BOWKER FERTILIZER Co., 43 Chatham St., Boston, Mass.

E 4 Corn Phosphate; Castleton.

J 5 Early Potato Manure; Bethel.

F 6 Hill and Drill Phosphate; Lyndonville.

E 3 Market Garden Fertilizer; Castleton.

G 1 Potash Bone; Bennington.

G 2 Potash or Staple Phosphate; Alburg.

F 5 and P 4 Potash and Vegetable Fertilizer; Plainfield.

E 6 Potato and Vegetable Phosphate; Castleton.

M 10 Soluble Potash Phosphate; Newport.

F 7 Square Brand Bone and Potash; Lyndonville.

A 16 Stockbridge Special Complete Manure for Corn and all Grain Crops; East Poultney.

A 15 Stockbridge Special Complete Manure for Potatoes and Vegetables; East Poultney.

K 12 Stockbridge Special Manure for Seeding Down; Brattleboro.

E 2 Stockbridge Special Complete Manure for Topdressing and for Forcing; Castleton.

M 9 Superphosphate with Potash; Arlington.

E 8 Sure Crop Bone Phosphate; Jericho.

E 5 Vermont Grange Chemicals, D Brand; Castleton.

J. F. BROMLEY, Granville, N. Y.

C 1 Banner Brand; Montpelier.

J 11 Corn and Potato Phosphate; East Berkshire.

M 5 Grass and Grain; Montpelier.

J 12 Green Mountain Brand; Waterbury.

C 3 Potato Special; Bethel.

C 4 Special Corn Fertilizer; Montpelier.

C 2 Special Potato Fertilizer; Montpelier.

BUFFALO FERTILIZER CO., William St., near city line, Buffalo,
N. Y.

- P 6 Celery and Potato Special*; Wolcott.
- M 2 Extra Phosphate and Potash*; Wolcott.
- E 15 Farmers Choice*; Wolcott.
- J 10 and P 24 Fish Guano*; Randolph.
- M 1 General Crop*; Montpelier.
- E 14 and P 7 High Grade Manure*; Middletown Springs.
- G 13 New England Special*; Cambridge.

BURLINGTON RENDERING CO., North Ave., Burlington, Vt.

- B 15 Animal Fertilizer*; Manchester.
- G 5 Grain Fertilizer*; Grand Isle.
- B 16 Special Potato Fertilizer*; Manchester Depot.
- G 4 Vegetable Fertilizer*; Stowe.

COE-MORTIMER CO., 51 Chambers St., New York, N. Y.

- B 2 Columbian Corn and Potato Fertilizer*; South Royalton.
- D 12 Extra Special Potato Fertilizer and Fruit Grower*; Morrisville.
- M 8 Famous Prize Brand Grain and Grass*; West Rupert.
- B 1 Gold Brand Excelsior Guano*; South Royalton.
- G 14 High Grade Ammoniated Bone Superphosphate*; Jeffersonville.
- D 10 New Englander Corn and Potato Fertilizer*; Morrisville.
- D 11 Standard Potato Fertilizer*; Morrisville.

ESSEX FERTILIZER CO., 39 North Market St., Boston, Mass.

- D 13 A1 Superphosphate*; Johnson.
- D 15 Complete Manure for Corn, Grain and Grass*; Johnson.
- B 10 Complete Manure for Potatoes, Roots and Vegetables*; Randolph.
- G 11 Grain, Grass and Potato Fertilizer*; Greensboro Bend.
- D 14 Market Garden and Potato Manure*; Johnson.
- B 11 XXX Fish and Potash*; Randolph.

HUBBARD FERTILIZER CO., Keyser Building, Baltimore, Md.

L 12 Royal Ensign; Guildhall.

LISTERS AGRICULTURAL CHEMICAL WORKS, Newark, N. J.

G 8 and P 10 G Brand; Plainfield.

M 6 Grass and Grain Fertilizer; Castleton.

D 6 Grass and Oats Fertilizer; Castleton.

E 9 Oneida Special; Jericho.

D 7 Potato Manure; Randolph.

D 5 Special Corn Fertilizer; Castleton.

D 8 Special Potato Fertilizer; Castleton.

G 10 Special Ten Percent Potato Fertilizer; Plainfield.

G 9 Success Fertilizer; Newport.

NATIONAL FERTILIZER COMPANY, 92 State St., Boston.

H 5 Chittenden's Ammoniated Bone; Woodstock.

J 4 Chittenden's Complete Root and Grain; Ludlow.

H 3 Chittenden's Eureka Potato Fertilizer; Woodstock.

K 11 Chittenden's High Grade Topdressing; Newfane.

H 4 Chittenden's Potato Phosphate; Ludlow.

J 3 Chittenden's Universal Phosphate; Ludlow.

NEW ENGLAND FERTILIZER CO., 42 North Market St., Boston,
Mass.

K 9 Complete Manure; Queechee.

II 7 Corn and Grain Fertilizer; Bennington.

H 6 Corn Phosphate; Sheldon.

II 9 Peerless Fertilizer; Danville.

II 8 Potato Fertilizer; Bradford.

K 10 Potato Grower; Underhill.

H 10 Superphosphate for all Crops; Sheldon.

PARMENTER AND POLSEY FERTILIZER CO., 40 North Market St.,
Boston, Mass.

F 13 Corn and Grain Fertilizer; Highgate.

F 11 Plymouth Rock Fertilizer; Danville.

F 14 Potato Fertilizer; Danville.

E 12 Potato Grower with Ten Percent Potash; Middlesex.

READING BONE FERTILIZER CO., 32-34 No. Sixth St., Reading, Pa.

- L 8 *All Crops Special*; Ferrisburgh.
- L 10 *Never Fail Crop Grower*; Ferrisburgh.
- K 8 *Prize Winner*; Proctor.
- L 9 *Special Potato and Tobacco*; Ferrisburgh.

ROGERS AND HUBBARD CO., Middletown, Conn.

- B 5 *Complete Phosphate*; Randolph.
- H 2 *Grass and Grain Fertilizer*; Newport.
- F 15 *New Market Garden Phosphate*; North Bennington.
- D 9 *Oats and Topdressing*; Randolph.
- F 16 *Potato Phosphate*; North Bennington.
- B 6 *Soluble Corn and General Crop Manure*; Randolph.
- D 16 *Soluble Potato Manure*; Hyde Park.
- K 13 *Soluble Tobacco Manure*; Healdville.

F. S. ROYSTER GUANO CO., Calvert Building, Baltimore, Md.

- E 12 *Complete Potato Manure*, Middletown Springs.
- E 13 *Gold Seal Potato and Tobacco*; Middletown Springs.
- E 11 *Imperial Formula*; Middletown Springs.

J. W. SANBORN, Pittsfield, New Hampshire.

- L 6 *Prof. Sanborn's Fertilizer for Grass and Grain*.
- L 5 *Prof. Sanborn's Fertilizer for Hill and Drill Use*.
- L 7 *Prof. Sanborn's Fertilizer for Potatoes and Corn*.

SANDERSON FERTILIZER AND CHEMICAL CO., New Haven Conn.

- B 3 *Atlantic Coast Bone, Fish and Potash*; East Poultney.
- B 4 *Corn Superphosphate*; East Poultney.
- L 4 *Potato Manure*; South Burlington.
- L 3 *Special with Ten Percent Potash*; Colchester.

SWIFT'S LOWELL FERTILIZER CO., 44 North Market St., Boston,
Mass.

- C 13 *Animal Brand for all Crops*; South Royalton.
- C 14 *Bone Fertilizer for Corn, Grain, Grass and Vegetables*;
St. Albans.

- G 6 *Cereal Fertilizer*; West Rupert.
C 15 *Empress Brand*; St. Albans.
J 13 *Potato Grower with Ten Percent. Potash*; Essex Junction.
D 1 *Potato Manure*; St. Albans.
G 7 *Potato Phosphate*; North Bennington.
C 16 *Special Corn and Vegetable Manure*; St. Albans.
J 2 *Special Grass Mixture*; Stowe.
D 2 *Special Potato Fertilizer*; St. Albans.
D 4 *Sterling Phosphate*; South Royalton.
J 14 *Superior Fertilizer with Ten Percent Potash*; Essex Junction.
D 3 *Vegetable and Vine Fertilizer*; St. Albans.

Special notice. The following brands licensed for sale in 1911 were not thus licensed in 1912.

Armour Fertilizer Works: Corn Special; General Farm; Oats and Clover Special.

Coe-Mortimer Co.: Special Potato and Fruit Grower.

Parmenter and Polsey Fertilizer Co.: Grain Grower; Star Brand Superphosphate.

Sanderson Fertilizer Co.: Formula A.

CONCERNING THE TABLES ON PAGES 292-307.

These tables, from the point of view of the execution of the law, form the essential part of the bulletin. Therein are displayed side by side what the fertilizer manufacturer says he will furnish and what he does furnish, the one in *italics*, the other in BLACK FACE. Furthermore all the details are given in order that the buyer may judge not only how much or how little plant food he gets for his money, but also how good or how inferior it is and what parts are good and what less good. While it is doubtless true that most buyers pay no attention whatsoever to the work of the control, many who have done so have profited thereby in getting a larger return in plant food for a dollar spent as a result of their study of the matter. And in order that such as may wish to grasp the full purport of these tables may be enabled to do so, there has been published from time to time brief explanatory matter, and, three years ago in bulletin 143, pages 183-192, a series of very full, almost painfully full, explanations of the meaning and significance of each piece of data. And there appears in this issue yet further explanation as to the nitrogen columns, last year for the first time thoroughly differentiated. This may be found on pages 265-266.

In brief it may be said that the parallel BLACK FACE and *italics* columns are the most serviceable means of comparing promises and actualities, so far as the quantity of plant food is concerned; and that the other figures, exclusive of the valuation, help one to determine more particularly its quality.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash†
Amer. Ag'l Chem. Co.																			
Grass and Lawn Topdress	2.03	1.24	0.23	0.09	....	3.59	3.91	\$11.99	3.95	2.05	0.50	6.50	6	6.00	5	\$5.40	13.02	2	\$2.96
Grass & Oats Fertilizer	....	....	....	....	....	....	....	....	7.56	3.74	0.88	12.18	12	11.30	11	10.14	2.66	2	2.26
High Grade Ten Percent	0.89	1.04	0.16	0.43	0.18	2.70	2.47	9.30	1.58	4.51	2.10	8.19	7	6.09	6	5.87	10.43	10	8.87
N. W. Chal. Crop Grower	....	0.16	0.54	0.31	0.18	1.19	1.03	4.43	4.24	3.25	3.61	11.10	9	7.49	8	7.86	2.46	2	2.09
Spec. Grass & Garden Mix.	3.06	0.23	1.51	3.15	0.47	8.42	8.43	30.36	1.24	4.61	1.83	7.68	7.25	5.85	6.25	5.54	9.78	8.25	8.31
XXX Phos. & Potash	....	....	....	....	....	....	....	....	5.64	4.20	1.14	10.98	11	9.84	10	8.90	9.82	8	8.35
Bradley Fertilizer Co. brands																			
Alk. Bone with Potash	....	....	....	....	....	....	....	....	6.44	4.30	1.30	12.04	12	10.74	11	9.76	2.46	2	2.09
Complete Corn & Grain	0.63	1.51	0.41	0.54	0.36	3.45	3.29	12.04	5.84	2.62	1.94	10.40	9	8.46	8	8.15	8.34	7	7.09
Complete Potato & Veg.	0.74	1.65	0.40	0.48	0.24	3.51	3.29	12.15	6.64	1.66	1.82	10.12	9	8.30	8	8.04	6.90	7	6.52
Complete Ten Percent	1.03	1.11	0.58	0.34	0.21	3.37	3.29	11.35	3.52	2.28	2.50	8.30	7	6.80	6	6.00	10.56	10	8.98
Complete Topdressing	0.65	1.10	0.50	1.89	0.73	4.97	4.94	17.64	3.36	1.82	1.18	6.36	6	5.18	4	4.95	7.31	6	6.21
Corn Phosphate	0.58	1.07	0.08	0.32	0.23	2.28	2.06	7.84	5.24	2.96	1.76	9.96	9	8.20	8	7.79	2.18	1.5	1.85
Eclipse Phosphate	....	0.29	0.27	0.50	0.34	1.40	1.03	5.17	4.60	3.26	1.70	9.56	9	7.86	8	7.43	2.54	2	2.16

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251. ‡Potash partly as sulphate.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water organic	Insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash†
Amer. Ag'l Chem. Co.																			
Bradley Fertilizer Co. brands—Cont.																			
Green Mountain Special	0.49	0.63	0.20	0.40	0.19	1.91	1.65	\$6.70	5.80	2.76	1.12	9.68	9.	8.56	8.	\$7.88	5.25	5.	\$4.46
H. G. Potato & Roots	0.91	0.21	0.08	0.43	0.29	1.92	1.65	6.74	4.76	3.46	1.62	9.84	9.	8.32	8.	7.70	10.38	10.	8.74
Niagara Phosphate	...	0.46	0.05	0.34	0.17	1.02	0.82	3.65	4.28	2.82	1.44	8.54	8.	7.10	7.	6.69	1.61	1.	1.37
Potato Fertilizer	0.84	0.32	0.27	0.59	0.30	2.32	2.06	8.24	6.00	2.36	2.84	11.90	9.	8.36	8.	8.43	3.35	3.	2.85
Potato Manure	0.45	0.79	0.30	0.80	0.28	2.62	2.47	9.33	4.44	2.40	1.98	8.82	7.	6.84	6.	6.71	5.67	5.	4.82
Vermont for all Crops	0.51	0.35	0.65	0.45	0.28	2.24	2.06	8.08	5.94	2.44	2.38	10.76	9.	8.88	8.	8.25	3.40	3.	2.89
XL Superphosphate	0.65	1.22	0.04	0.60	0.24	2.75	2.47	9.51	5.32	3.48	1.62	10.42	10.	8.80	9.	8.22	2.30	2.	1.95
Clark's Cove Fertilizer Co. brands																			
Bay State Fertilizer G. G.	0.18	0.77	0.41	0.66	0.32	2.34	2.06	8.42	5.08	3.30	1.96	10.34	9.	8.38	8.	7.99	1.72	1.5	1.46
King Philip Alk. Guano	...	0.11	0.05	0.63	0.30	1.09	1.03	4.08	4.52	3.63	2.04	10.19	9.	8.15	8.	7.79	2.30	2.	1.96
Potato Fertilizer	0.53	1.03	0.25	0.37	0.23	2.41	2.06	8.38	5.36	3.08	1.66	10.10	9.	8.44	8.	7.94	3.70	3.	3.15
Cleveland Dryer Co. brands																			
Fertilizer for All Crops	...	0.32	0.25	0.37	0.25	1.19	1.03	4.37	5.08	3.02	2.38	10.48	9.	8.10	8.	7.94	2.59	2.	2.20

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitrogen	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phosphoric acid	Round	Guaranteed	Valuation of potash
Amer. Ag'l Chem. Co.																			
<i>Cleveland Dryer Co. brands.—Cont.</i>																			
Potato Phosphate	0.73	0.93	0.18	0.42	0.23	2.49	2.06	\$8.63	6.00	2.38	0.82	9.20	9.	8.38	8.	\$7.62	3.47	3.	\$2.95
Superphosphate	0.66	0.95	0.13	0.45	0.22	2.41	2.06	8.35	4.68	3.66	1.46	9.80	9.	8.34	8.	7.72	2.49	1.5	2.12
<i>Crocker Fertilizer & Chemical Co. brands</i>																			
Ammo. Corn Phosphate	0.60	0.86	0.19	0.49	0.20	2.34	2.06	8.20	4.28	3.46	1.72	9.46	9.	7.74	8.	7.31	1.70	1.5	1.44
New Rival Ammo. Super.	....	0.25	0.27	0.49	0.25	1.26	1.03	4.67	4.84	3.17	1.84	9.85	9.	8.01	8.	7.64	2.43	2.	2.07
Potato, Hop & Tobacco	0.51	0.70	0.21	0.61	0.23	2.26	2.06	7.98	5.52	2.60	1.90	10.02	9.	8.12	8.	7.81	3.01	3.	2.56
Special Potato Manure	0.87	1.30	0.15	0.81	0.28	3.41	3.29	11.87	4.40	2.36	1.30	8.06	7.	6.76	6.	6.37	10.10	10.	8.59
<i>Cumberland Bone Phosphate Co. brands</i>																			
Guano for All Crops	....	0.28	0.30	0.43	0.20	1.21	1.03	4.45	5.60	3.22	2.30	11.12	9.	8.82	8.	8.53	2.47	2.	2.10
Potato Fertilizer	0.42	0.81	0.19	0.72	0.28	2.42	2.06	8.58	5.88	2.12	2.20	10.20	9.	8.00	8.	7.87	3.18	3.	2.70
Superphosphate	0.65	0.88	0.19	0.45	0.18	2.35	2.06	8.17	4.64	3.48	1.46	9.58	9.	8.12	8.	7.54	1.86	1.5	1.58
<i>Darling Fertilizer Co. brands</i>																			
Farm Favorite	0.68	0.93	0.17	0.40	0.23	2.41	2.06	8.35	6.12	2.72	1.20	10.04	9.	8.84	8.	8.17	3.05	3.	2.59

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash†
Amer. Ag'l Chem. Co.																			
Darling Fertilizer Co. brands—Cont.																			
General Fertilizer	...	0.23	0.34	0.55	0.29	1.41	1.23	\$5.24	4.64	2.12	1.92	8.68	7.	6.76	6.	\$6.65	3.78	3.	\$3.21
East India Chemical Co. brands																			
Complete Potato Manure	0.98	1.50	0.38	0.53	0.19	3.58	3.29	12.36	3.96	2.96	2.02	8.94	7.	6.92	6.	6.74	10.48	10.	8.87
Harvest Home Fertilizer	...	0.28	0.35	0.38	0.20	1.21	1.05	4.45	5.64	2.52	2.32	10.48	9.	8.16	8.	8.03	2.36	2.	2.01
Standard UNXID Fert.	0.75	0.37	0.20	0.71	0.27	2.30	1.65	8.18	4.64	3.42	1.56	9.62	9.	8.06	8.	7.54	4.78	2.	4.06
Great Eastern Fertilizer Co. brands																			
Garden Special	0.95	1.07	0.68	0.46	0.28	3.44	3.29	12.07	5.88	3.54	3.64	13.06	9.	9.42	8.	9.58	7.48	7.	6.36
General Fertilizer	0.11	0.42	0.08	0.25	0.14	1.00	0.82	3.54	5.52	2.52	1.68	9.72	9.	8.04	8.	7.65	4.90	4.	4.17
Northern Corn Special	0.74	0.14	0.21	0.50	0.24	1.38	2.06	6.51	3.04	3.81	2.91	9.76	9.	6.85	8.	6.95	1.92	1.5	1.63
Potato Manure	0.69	0.47	0.41	0.39	0.21	2.17	2.06	7.67	4.32	4.26	2.24	10.82	9.	8.58	8.	8.20	3.17	3.	2.69
Pacific Guano Co. brands																			
Nobisque Guano	...	0.18	0.19	0.56	0.26	1.19	1.03	4.44	3.94	3.54	2.25	9.78	9.	7.48	8.	7.28	2.64	2.	2.24
Potato Special	...	0.93	0.50	0.57	0.30	2.30	2.06	8.28	5.22	2.85	2.99	11.06	9.	8.07	8.	8.18	3.46	3.	2.94

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH					
	In nitrates	In ammonia salts	Water soluble organic	Active water organic	Inactive water organic	Insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash‡
Amer. Ag'l Chem. Co.																				
Pacific Guano Co. brands.—Cont.																				
Soluble Pacific Guano	0.77	0.13	0.33	0.49	0.28	0.28	2.00	2.06	\$7.15	3.71	3.74	2.83	10.28	9.	7.45	8.	\$7.46	2.19	1.5	\$1.86
Quinnipiac Co. brands																				
Climax Phosphate	....	0.28	0.24	0.45	0.28	0.28	1.35	1.03	4.61	5.44	2.98	1.94	10.36	9.	8.42	8.	8.05	2.25	2.	1.91
Corn Manure	0.94	0.88	0.11	0.45	0.24	0.24	2.32	2.06	8.06	4.76	3.56	1.40	9.72	9.	8.32	8.	7.69	1.86	1.5	1.58
Market Garden Manure	0.94	1.16	0.57	0.53	0.29	0.29	3.49	3.29	12.21	6.04	2.40	4.42	12.86	9.	8.44	8.	9.13	6.85	7.	5.82
Potato Phosphate	0.69	0.96	0.17	0.30	0.18	0.18	2.30	2.06	7.92	6.24	2.50	1.04	9.78	9.	8.74	8.	8.04	3.06	5.	2.60
Read Fertilizer Co. brands																				
Farmers' Friend Super.	0.51	0.79	0.37	0.49	0.21	0.21	2.37	2.06	8.36	5.44	2.94	1.84	10.22	9.	8.38	8.	7.99	3.04	3.	2.58
High Grade Far's Friend	0.94	1.26	0.08	0.73	0.29	0.29	3.30	3.29	11.44	4.08	2.50	1.00	7.58	7.	6.58	6.	6.07	9.98	10.	8.44
Leader Blood & Bone	....	0.18	0.17	0.44	0.21	0.21	1.00	0.82	3.71	4.62	2.92	2.00	9.54	8.	7.54	7.	7.30	4.45	1.	3.78
Potato Manure	0.12	1.27	0.31	0.72	0.36	0.36	2.78	2.47	9.88	3.43	3.00	1.63	8.06	7.	6.48	6.	6.14	9.84	10.	8.38
Practical Potato Special	....	0.25	0.18	0.44	0.24	0.24	1.11	0.82	4.10	2.54	1.91	1.45	5.90	5.	4.45	4.	4.40	7.70	8.	6.55
Standard Superphosphate	....	0.25	0.17	0.43	0.24	0.24	1.09	0.82	4.02	4.96	2.86	1.62	9.44	9.	7.82	8.	7.40	4.48	4.	3.77

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble	Active water organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash†
Amer. Ag'l Chem. Co.																			
<i>Read Fertilizer Co. brands.—Cont.</i>																			
Sure Catch Fertilizer	....	....	....	....	....	....	....	\$.....	6.56	3.96	0.98	11.50	11.	10.52	10.	\$9.46	2.78	2.	\$2.32
H. F. Tucker Co. brands																			
Imperial for All Crops	....	0.12	0.01	0.66	0.32	1.11	1.03	4.16	4.60	3.52	2.00	10.12	9.	8.12	8.	7.76	2.42	2.	2.06
Imperial for Corn	....	....	0.21	0.58	0.28	1.07	1.03	4.07	4.58	3.80	2.00	10.38	9.	8.38	8.	7.96	2.40	2.	2.07
Imperial for Potatoes	....	0.11	0.07	0.65	0.24	1.07	1.03	4.01	4.92	3.65	1.87	10.44	9.	8.57	8.	8.10	2.36	2.	2.01
Williams & Clark Fertilizer Co. brands																			
Amer. Ammo. Bone Super.	0.66	1.21	0.05	0.55	0.29	2.76	2.47	9.55	5.56	3.06	1.74	10.36	10.	8.62	9.	8.15	2.06	2.	1.75
Amer. Corn Phosphate	0.74	0.78	0.06	0.50	0.24	2.32	2.06	8.06	2.64	4.36	1.62	8.62	9.	7.00	8.	6.52	1.91	1.5	1.62
High Grade Spec. Pot. etc.	1.55	0.20	0.35	1.10	0.38	3.58	3.29	12.73	4.52	3.84	1.30	9.66	9.	8.36	8.	7.66	8.10	7.	6.89
Amer. Potato Manure	0.86	0.25	0.48	0.28	0.21	2.08	2.06	7.35	5.20	2.99	2.01	10.20	9.	8.19	8.	7.87	2.05	3.	2.59
Potato Phosphate	0.50	0.90	0.04	0.60	0.33	2.37	2.47	8.31	4.64	1.55	1.03	7.22	7.	6.19	6.	5.83	5.16	5.	4.39
Prolific Crop Producer	....	0.46	0.24	0.24	0.18	1.12	0.82	4.03	5.64	1.90	1.94	9.48	8.	7.54	7.	7.37	1.50	1.	1.28
Royal Bone Phosphate	....	0.13	0.47	0.30	0.28	1.18	1.03	4.42	4.24	3.51	3.47	11.22	9.	7.75	8.	8.02	2.00	2.	1.70

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water organic	Inactive water organic	Total found	Total guaranteed	Valuation of nitro- gen‡	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid‡	Found	Guaranteed	Valuation of potash‡
Armour Fertilizer Works																			
Banner Brand	....	....	....	....	....	....	....	\$.....	8.16	2.80	0.56	11.52	10.5	10.96	10.	\$9.80	8.61	8.	\$7.32
Bean and Farm Fertilizer	....	....	....	....	....	....	....	....	5.96	2.32	0.38	8.66	8.5	8.98	8.	7.37	4.55	4.	3.87
Complete Manure	1.46	0.21	0.56	0.88	0.49	3.60	3.3	12.84	3.44	3.06	0.62	7.12	6.5	6.50	6.	5.80	10.18	10.	8.65
Fruit and Root Crop Spec.	0.48	0.17	0.46	0.45	0.31	1.87	1.65	6.79	4.96	2.98	0.62	8.56	8.5	7.94	8.	7.09	5.66	5.	4.81
High Grade Potato	0.52	0.16	0.33	0.44	0.39	1.84	1.65	6.65	5.60	2.60	1.24	9.44	8.5	8.90	8.	7.62	11.10	10.	9.44
Trucker Special	1.45	0.18	0.42	0.74	0.46	3.25	3.3	11.54	3.68	3.66	1.48	8.82	6.5	7.34	6.	6.83	9.80	10.	8.33
Bowker Fertilizer Co.																			
Corn Phosphate	0.18	0.61	0.55	0.44	0.24	2.02	1.65	7.28	6.16	2.14	2.00	10.30	9.	8.90	8.	8.02	2.18	2.	1.85
Early Potato Manure	0.78	1.61	0.41	0.53	0.23	3.56	3.29	12.34	6.32	2.36	1.76	10.44	9.	8.68	8.	8.28	7.06	7.	6.00
Hill and Drill Phosphate	0.87	0.23	0.55	0.50	0.27	2.42	2.47	8.65	7.06	2.66	3.66	13.38	10.	9.72	9.	9.94	2.45	2.	2.08
Market Garden Fertilizer	....	1.04	0.74	0.60	0.29	2.67	2.47	9.62	4.72	2.12	1.24	8.08	7.	6.84	6.	6.45	10.29	10.	8.75
Potash Bone	....	0.16	0.20	0.46	0.23	1.05	0.82	3.91	3.44	3.44	1.30	8.18	7.	6.88	6.	6.37	3.01	2.	2.56
Potash or Staple Phos.	....	0.46	0.16	0.26	0.16	1.04	0.82	3.72	5.24	2.70	1.78	9.72	9.	7.94	8.	7.59	4.99	3.	4.24
Potato and Veg. Fert.	0.56	0.79	0.34	0.45	0.25	2.39	2.47	8.42	5.90	1.84	1.74	9.48	9.	7.74	8.	7.48	4.51	4.	3.83

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN					PHOSPHORIC ACID								POTASH					
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash‡
Bowker Fertilizer Co.—Cont.																			
Potato and Veg. Phos.	....	0.67	0.65	0.43	0.25	2.00	1.65	\$7.26	6.28	2.40	1.84	10.52	9.	8.68	8.	\$8.31	2.14	2.	\$1.82
Soluble Potash Phosphate	....	....	....	....	....	....	....	....	6.80	3.30	1.18	11.28	11.	10.10	10.	9.23	8.00	8.	6.80
Square Brand Bone & Pot.	0.63	0.21	0.53	0.44	0.26	2.07	1.65	7.44	5.12	2.40	3.48	11.00	7.	7.52	6.	7.92	2.28	2.	1.94
Stockbridge Corn & Grain	0.36	1.05	0.16	0.81	0.35	3.22	3.29	11.28	6.96	3.41	1.39	11.76	11.	10.37	10.	9.55	6.94	7.	5.90
Stockbridge Potato & Veg.	1.10	1.07	0.08	0.68	0.32	3.25	3.29	11.26	5.08	1.10	1.12	7.30	7.	6.18	6.	5.90	10.16	10.	8.64
Stockbridge Seeding Down	0.63	1.23	0.22	0.47	0.22	2.77	2.47	9.67	8.64	1.98	1.32	11.94	11.	10.62	10.	9.39	*7.62	8.	7.87
Stockbridge Topdressing	2.44	2.40	0.27	0.07	....	5.18	4.94	17.26	3.52	0.60	2.16	6.28	6.	4.12	4.	4.51	5.90	6.	5.02
Superphos. with Potash	....	....	....	....	....	....	....	....	8.68	2.72	1.48	12.88	11.	11.40	10.	10.58	3.28	2.	2.75
Sure Crop Bone Phos.	....	0.27	0.18	0.39	0.22	1.06	0.82	3.89	5.00	3.01	2.70	10.71	9.	8.01	8.	7.99	2.01	2.	1.71
Vt. Grange, Ch. D. Brand	....	0.60	0.74	0.53	0.31	2.18	2.06	7.98	5.40	2.60	2.56	10.56	9.	8.00	8.	7.96	3.08	3.	2.62
J. F. Bromley																			
Banner Brand	2.30	0.35	0.29	0.49	0.31	3.74	3.29	12.89	6.64	1.64	0.66	8.94	8.5	8.28	8.	7.55	9.90	9.	8.42
Corn and Potato	0.52	0.20	0.24	0.36	0.34	1.66	1.23	5.95	2.96	5.88	1.18	10.02	9.	8.84	8.5	7.83	3.14	2.5	2.67

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gen	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid	Found	Guaranteed	Valuation of potash
J. F. Bromley—Cont.																			
Grain and Grass	...	...	...	...	...	...	...	\$.....	5.36	4.88	0.74	10.96	10.5	10.24	10	\$9.02	2.58	2	\$2.19
Green Mountain Brand	0.46	0.26	0.17	0.49	0.32	1.70	1.25	6.09	6.60	2.48	0.94	10.02	8.5	9.08	8	8.30	6.04	5	5.13
Potato Special	0.74	0.21	0.07	0.52	0.35	1.89	1.65	6.71	6.36	1.92	0.84	9.12	8.5	8.98	8	7.60	19.64	10	9.06
Special Corn Fertilizer	...	0.25	0.05	0.40	0.30	1.00	0.82	3.68	3.64	3.62	1.13	8.39	8	7.26	7.5	6.63	8.47	5	2.95
Special Potato Fertilizer	...	0.28	0.04	0.41	0.27	1.00	0.82	3.66	3.28	4.14	1.14	8.56	8	7.42	7.5	6.72	8.51	5	2.98
Buffalo Fertilizer Co.																			
Celery and Potato Special	...	1.54	0.02	0.20	0.14	1.90	1.6	6.45	7.12	2.20	0.88	10.20	9	9.32	8	8.52	9.71	10	8.25
Extra Phos. with Potash	...	...	...	...	...	...	...	...	5.44	5.30	2.04	12.78	11	10.74	10	9.76	8.00	8	6.80
Farmers' Choice	...	0.44	0.16	0.25	0.29	1.14	0.8	4.11	5.36	2.70	1.84	9.90	9	8.06	8	7.71	5.16	5	4.39
Fish Guano	...	0.39	0.25	0.35	0.23	1.22	0.8	4.45	4.28	4.77	2.52	11.57	10	9.05	9	8.70	4.04	2	3.44
General Crop	...	...	...	...	...	...	...	...	6.20	3.98	0.72	10.90	10	10.18	9	9.05	8.64	5	3.09
High Grade Manure	0.73	1.24	0.54	0.49	0.28	2.26	5.5	11.48	2.55	5.09	2.03	9.67	8	7.64	7	7.18	10.82	10	9.20
New England Special	...	1.16	0.12	0.47	0.30	2.05	1.6	7.21	5.98	3.46	1.52	10.96	10	9.44	9	8.76	5.91	5	5.03

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251. ‡Potash partly as sulphate.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID								POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Round	Guaranteed	Valuation of potash†
Burlington Rendering Co.																			
Animal Fertilizer	...	0.89	0.65	0.54	0.48	2.56	2.	\$9.29	3.32	2.50	2.96	8.78	8.	5.92	5.	\$6.19	4.50	4.	\$3.83
Grain Fertilizer	...	0.32	0.26	0.33	0.32	1.28	1.	4.52	5.24	2.54	0.80	8.58	8.	7.78	7.	7.07	4.18	4.	3.51
Special Potato Fertilizer	...	1.27	0.38	0.49	0.42	2.56	2.46	9.09	2.88	2.84	2.88	8.60	8.	5.72	5.	6.01	6.54	6.	5.56
Vegetable Fertilizer	...	1.20	0.36	0.50	0.43	2.49	2.46	8.86	4.92	2.51	1.75	9.18	8.	7.48	7.	7.14	10.96	10.	9.32
Coe-Mortimer Co.																			
Columbian Corn and Pot.	0.46	0.26	0.09	0.44	0.21	1.46	1.23	5.19	4.52	3.83	1.67	10.02	9.5	8.95	8.5	7.81	3.50	2.5	2.98
Extra Special Potato	0.21	1.23	0.21	0.20	0.12	1.97	1.65	6.81	4.24	4.21	0.30	8.75	9.	8.45	8.	7.31	9.98	10.	8.44
Fam. Prize Br. Grass & Gr.	...	...	...	...	...	...	...	...	8.08	3.22	1.06	12.36	11.	11.30	10.	10.27	2.54	2.	2.16
Gold Brand Excel. Guano	0.56	1.09	0.18	0.46	0.21	2.50	2.47	8.68	5.80	2.92	1.88	10.60	9.	8.72	8.	8.31	6.58	6.	5.59
H. G. Ammo. Bone Super.	...	0.40	0.70	0.50	0.31	1.91	1.85	7.06	6.36	2.54	2.12	11.02	9.	8.90	8.	8.60	3.39	3.	2.88
N. E. Corn and Potato	...	0.25	0.31	0.24	0.20	1.00	0.8	3.68	4.80	2.60	2.46	9.86	8.5	7.40	7.5	7.39	3.62	3.	3.08
Standard Potato Fertilizer	0.55	1.42	0.58	0.61	0.30	3.46	3.3	12.16	4.84	1.48	1.78	8.10	7.	6.32	6.	6.26	10.57	10.	8.98

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash†
Essex Fertilizer Co.																			
A 1 Superphosphate	...	0.11	0.60	0.43	0.23	1.37	1.25	\$5.15	4.44	2.50	0.94	7.88	8.	6.94	7.	\$6.38	2.44	2.	\$2.07
Complete for Corn & Gr.	1.38	0.11	0.96	0.57	0.30	3.32	3.28	11.87	4.00	2.16	1.22	7.38	7.	6.16	6.	5.32	10.07	10.	8.56
Complete for Pot., etc.	1.56	0.13	0.82	0.66	0.34	3.51	3.28	12.50	5.24	1.52	1.18	7.94	7.	6.76	6.	6.42	9.96	10.	8.47
Grain, Grass & Pot. Fert.	...	...	0.61	0.17	0.15	0.93	0.82	3.53	5.76	2.01	1.55	9.33	9.	7.77	8.	7.42	4.39	4.	3.73
Market Garden & Potato	...	0.49	0.60	0.75	0.32	2.16	2.	7.97	6.44	2.10	0.72	9.26	9.	8.54	8.	7.77	5.44	5.	4.62
XXX Fish and Potash	0.79	0.11	0.47	0.54	0.27	2.18	2.	7.83	6.44	1.86	0.98	9.28	9.	8.30	8.	7.68	3.53	3.	3.00
Hubbard Fertilizer Co.																			
Royal Ensign	1.00	0.12	0.48	0.35	0.28	2.23	2.46	7.92	5.32	2.98	1.60	9.90	...	8.30	8.	7.81	4.90	4.	4.08
Lister's Ag'l Chem. Works																			
G Brand	...	0.18	0.89	0.27	0.26	1.10	0.82	4.09	5.44	2.23	1.71	9.38	9.	7.67	8.	7.36	4.48	4.	3.81
Grass and Grain Fert.	...	...	...	...	...	...	...	...	8.08	2.04	1.02	11.14	11.	10.12	10.	9.31	3.29	2.	2.80
Grass and Oats Fert.	...	0.18	0.35	0.27	0.24	1.04	0.82	3.86	5.88	2.56	1.40	9.84	9.	8.44	8.	7.90	4.35	4.	3.70
Onelda Special	0.17	0.18	0.53	0.27	0.29	1.44	0.82	5.30	4.84	2.32	1.50	8.66	8.	7.16	7.	6.82	1.46	1.	1.24

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN					PHOSPHORIC ACID							POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash†
Lister's Ag'l Chem. Works—Cont.																			
Potato Manure	....	1.86	0.76	0.48	0.36	3.46	3.29	\$12.22	6.64	2.10	1.74	10.48	9.	8.74	8.	\$8.36	7.70	7.	\$6.55
Special Corn Fertilizer	....	0.18	0.53	0.32	0.27	1.80	1.23	4.85	6.16	2.72	1.52	10.40	9.	8.88	8.	8.33	8.32	5.	2.82
Special Potato Fertilizer	....	0.21	0.74	0.55	0.43	1.98	1.65	7.23	5.04	2.62	2.32	9.98	9.	7.66	8.	7.57	8.56	3.	3.02
Special Ten Percent Pot.	....	0.18	0.60	0.50	0.41	1.69	1.65	6.33	6.32	2.36	1.44	10.12	9.	8.68	8.	8.15	10.38	10.	8.82
Success Fertilizer	....	0.16	0.67	0.37	0.33	1.53	1.23	5.74	6.24	2.90	1.84	10.98	10.	9.14	9.	8.68	2.24	2.	1.90
National Fertilizer Co.																			
Chittenden Ammo. Bone	0.63	0.11	0.04	0.64	0.26	1.68	1.65	6.01	4.84	3.04	1.43	9.31	9.	7.88	8.	7.36	2.31	2.	1.96
Chitt'n Comp. Root, etc.	1.47	0.23	0.33	1.28	0.41	3.72	3.29	13.29	4.60	4.28	2.00	10.88	9.	8.88	8.	8.37	7.15	6.	6.08
Chittenden Eureka Potato	0.67	0.95	0.24	0.48	0.22	2.56	2.47	8.92	4.52	2.36	1.24	8.12	7.	6.88	6.	6.47	9.60	10.	8.16
Chitt'n H. G. Topdressing.	4.57	0.18	0.78	1.75	0.55	7.83	8.43	27.38	1.00	4.78	3.94	9.72	7.	7.25	5.78	6.25	8.34	8.	7.09
Chittenden Potato Phos.	....	1.09	0.50	0.46	0.28	2.33	2.06	8.31	6.00	2.58	2.36	10.94	9.	8.58	8.	8.42	6.97	6.	5.92
Chitt'n Universal Phos.	....	0.21	0.21	0.38	0.22	1.02	0.82	3.77	5.04	3.10	1.72	9.86	9.	8.14	8.	7.71	1.88	5.	1.60

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gen†	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash†
New England Fertilizer Co.																			
Complete Manure	1.49	0.14	0.90	0.68	0.30	3.51	3.28	\$12.52	4.68	1.84	0.70	7.22	7.652	6.35.96	10.37	10.38.31			\$8.81
Corn and Grain Fertilizer	...	0.16	0.69	0.29	0.17	1.23	4.90	8.70	4.48	3.20	1.02	8.70	8.768	7.7.00	2.15	2.183			1.83
Corn Phosphate	0.37	0.12	0.89	0.28	0.20	1.64	6.83	6.08	6.83	2.62	1.44	10.14	9.8.70	8.8.14	3.29	3.280			2.80
Peerless Fertilizer	...	0.10	0.48	0.34	0.19	1.11	0.82	4.17	5.12	2.36	1.16	8.64	8.7.48	7.6.96	1.64	1.39			1.39
Potato Fertilizer	...	0.42	0.79	0.42	0.20	1.83	1.64	6.75	4.76	2.20	1.12	8.08	8.6.96	7.6.49	4.24	4.3.60			3.60
Pot. Grower with 10% Pot.	...	1.21	0.87	0.52	0.24	2.84	2.46	10.18	4.48	2.20	0.90	7.58	7.6.68	6.6.15	10.34	10.8.79			8.79
Superphos. for All Crops	0.69	0.12	0.91	0.50	0.27	2.49	2.46	9.05	6.84	1.54	0.76	9.14	9.8.38	8.7.69	14.31	4.4.03			4.03
Parmenter and Polsey Fertilizer Co.																			
Corn and Grain Fertilizer	...	0.11	0.49	0.29	0.16	1.05	0.82	3.93	6.48	1.83	2.51	10.82	9.8.31	8.8.29	4.39	4.3.73			3.73
Plymouth Rock Fertilizer	0.66	0.14	1.15	0.49	0.23	2.67	2.46	9.75	6.78	1.83	0.82	9.48	9.8.61	8.7.89	4.47	4.3.80			3.80
Potato Fertilizer	...	0.11	0.89	0.50	0.27	1.77	1.64	6.67	4.78	2.79	1.18	8.75	7.7.57	6.7.00	6.76	6.5.75			5.75
Pot. Grower with 10% Pot.	0.76	0.46	0.63	0.66	0.23	2.74	2.46	9.81	5.10	1.71	0.65	7.46	7.6.31	6.6.22	10.56	10.8.98			8.98

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gen†	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash†
Reading Bone Fertilizer Co.																			
All Crops Special	....	0.95	0.15	0.26	0.29	1.65	1.64	\$5.80	2.16	4.58	1.18	7.92	8.	6.74	7.	\$6.07	7.72	5.	\$6.56
Never Fall Crop Grower	....	0.32	0.01	0.25	0.30	0.88	0.82	3.19	2.24	5.14	1.40	8.78	9.	7.38	8.	6.69	1.57	1.	1.33
Prize Winner	....	1.93	0.18	0.30	0.14	2.55	2.47	8.73	5.44	3.58	1.92	10.94	10.	9.02	9.	8.45	12.90	12.	10.37
Special Potato & Tobacco	...	0.18	0.14	0.24	0.44	1.00	0.82	3.71	2.08	4.36	1.08	7.52	7.	6.44	6.	5.79	7.77	7.	6.60
Rogers & Hubbard Co.																			
Complete Phosphate	0.29	0.13	0.23	0.63	0.35	1.63	1.5	5.99	4.40	2.65	2.23	9.28	8.	7.05	7.	6.98	6.06	5.	5.15
Grass and Grain Fert.	0.34	0.17	0.58	0.83	0.38	2.30	2.2	8.48	0.08	7.30	7.66	15.04	16.	7.38	6.5	8.97	11.95	12.	10.16
New Market Garden Fert.	0.81	0.14	0.25	0.81	0.31	2.32	2.	8.35	3.14	2.93	2.45	8.52	7.	6.07	6.	6.15	11.32	10.	9.62
Oats and Topdressing	8.02	0.11	0.12	0.50	0.13	8.58	8.5	29.68	0.12	5.98	3.60	9.70	8.	6.10	4.5	6.32	7.90	8.	6.63
Potato Phosphate	0.78	0.12	0.30	0.68	0.35	2.23	2.	8.02	6.64	2.61	1.93	11.18	10.	9.25	9.	8.84	6.47	5.	5.50
Sol. Corn and Gen'l Crops	1.36	0.11	0.49	0.61	0.34	2.91	2.5	10.32	2.52	3.33	3.06	8.91	8.	5.85	6.	6.16	9.44	8.	8.02
Soluble Potato Manure	2.30	0.35	0.53	1.22	0.74	5.14	5.	18.21	1.24	6.55	3.81	11.60	10.	7.79	7.	7.88	*6.25	5.	6.47
Soluble Tobacco Manure	2.06	0.35	0.59	1.82	0.48	5.30	5.	18.93	1.56	6.86	4.12	12.54	10.	8.42	7.	8.54	*10.16	10.	10.56

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251. ‡Potash partly as sulphate.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Valuation of nitro- gent	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid	Found	Guaranteed	Valuation of potash		
F. S. Royster Guano Co.																			
Complete Potato Manure	....	1.76	0.30	0.82	0.53	8.41	3.29	\$12.08	3.08	2.55	2.41	8.04	6.5	5.63	6	\$5.78	10.46	10.	\$8.89
Gold Seal Pot. & Tobacco	....	0.86	0.21	0.50	0.43	2.00	1.65	7.17	5.56	2.46	0.76	8.78	8.5	8.02	8.	7.27	9.90	10.	8.42
Imperial Formula	....	0.47	0.08	0.22	0.27	1.04	0.82	3.72	5.24	2.80	0.86	8.90	8.5	8.04	8.	7.30	5.04	4.	4.28
J. W. Sanborn.																			
For Grass and Grain	4.19	0.12	0.41	0.49	0.30	5.51	5.15	18.78	5.88	1.70	0.74	8.32	7.	7.58	4.	6.95	6.78	6.	5.76
For Hill and Drill Use	1.38	0.12	0.49	0.72	0.38	3.09	2.5	10.99	4.20	2.78	4.58	11.56	12.	6.98	7.	7.84	5.12	4.	4.35
For Potatoes and Corn	1.17	0.16	0.35	1.68	0.69	4.05	3.5	14.73	4.84	2.60	2.98	10.42	10.	7.44	7.	7.63	*8.02	8.	7.82
Sanderson Fertilizer & Chemical Co.																			
Atlantic Bone, Fish & Pot.	....	0.35	0.33	0.72	0.62	2.02	1.67	7.51	1.52	3.30	2.26	7.08	6.	4.91	4.	4.91	4.36	4.	3.71
Corn Superphosphate	0.14	0.23	0.33	0.67	0.47	1.84	1.67	6.81	3.88	3.16	3.34	10.38	9.	7.04	7.	7.36	3.36	2.	2.86
Potato Manure	....	0.53	0.45	0.67	0.49	2.14	1.67	7.87	3.40	2.32	2.58	8.30	8.	5.72	5.	5.95	7.48	6.	6.36
Special Ten Percent Pot.	....	1.26	0.39	0.76	0.47	2.88	2.47	10.32	5.64	0.42	3.14	9.20	8.	6.06	5.	6.68	10.74	10.	9.13

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitrogen	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phosphoric acid	Round	Guaranteed	Valuation of potash
Swift's Lowell Fertilizer Co.																			
Animal Br. for All Crops	0.74	0.14	1.21	0.51	0.28	2.88	2.46	\$10.50	6.76	2.32	1.00	10.08	9.	9.08	8.	\$8.34	4.46	4.	\$3.79
Bone Fert. for Corn & Gr.	0.35	0.11	0.79	0.38	0.21	1.84	1.64	6.76	6.32	2.46	1.78	10.56	9.	8.78	8.	8.37	3.59	3.	3.05
Cereal Fertilizer	....	....	0.42	0.33	0.18	0.93	0.82	3.53	4.40	2.82	1.06	8.98	8.	7.92	7.	6.64	1.82	1.	1.12
Empress Brand	....	0.14	0.43	0.41	0.29	1.37	1.25	4.75	4.84	2.19	1.05	8.08	8.	7.08	7.	6.52	2.30	2.	1.96
Pot. Grower with 10% Pot.	1.14	0.14	0.68	1.22	0.47	3.65	3.28	13.23	5.04	1.52	1.46	8.02	7.	6.56	6.	6.34	10.90	10.	9.27
Potato Manure	0.35	0.11	0.62	0.38	0.29	1.75	1.64	6.42	5.92	1.96	1.02	8.90	8.	7.88	7.	7.30	4.78	4.	4.06
Potato Phosphate	1.12	0.12	0.44	0.69	0.28	2.65	2.46	9.45	6.76	1.88	0.60	9.04	9.	8.64	8.	7.82	6.16	6.	5.24
Special Corn and Veg.	1.10	0.11	0.90	0.87	0.34	3.32	3.28	12.01	6.12	2.16	0.94	9.32	9.	8.38	8.	7.62	7.78	7.	6.61
Special Grass Mixture	....	2.26	0.97	0.64	0.29	4.16	4.1	14.68	6.52	1.22	0.56	8.30	8.	7.74	7.	7.07	6.48	6.	5.51
Special Potato Fertilizer	0.84	0.46	0.72	0.61	0.30	2.98	2.46	10.48	4.96	2.00	0.80	7.76	7.	6.96	6.	6.38	10.78	10.	9.16
Sterling Phosphate	....	0.11	0.53	0.22	0.16	1.02	0.82	3.82	6.08	2.66	1.14	9.88	9.	8.74	8.	8.06	4.84	4.	3.69
Superior Fert., 10% Pot.	0.12	1.67	0.79	0.65	0.40	3.63	3.69	13.02	6.76	1.64	0.62	9.02	8.	8.40	7.	7.64	9.90	10.	8.42
Veg. and Grain Fertilizer	0.38	0.11	0.92	0.43	0.27	2.11	1.64	7.78	6.68	2.46	1.52	10.66	9.	9.14	8.	8.59	10.74	10.	9.13

*Potash in brands thus marked is largely if not entirely as sulphate. †See definition, page 251.

VI. ANALYSES OF FERTILIZERS FOR FIVE YEARS, 1908-1912

The buyer of mixed goods usually makes his choice before the analyses are published. The Station usually prints its bulletin in early July. This date is well in advance of the issuance of similar figures by other northern stations, yet the information they convey usually reaches the buyer too late to be of service; and if station analyses are consulted at all, those of former years are used. These may or may not be safe guides. If, however, reference to analyses of successive years shows essential uniformity of composition in the past and an unchanged guaranty, the buyer is safe in assuming that the former figures will be applicable. If the guaranty statement has been changed, and if former statements have been lived up to in the past, the presumption is in favor of similar keeping of promises for the present year.

In order to facilitate such reference and to indicate something of the evenness or variation in composition from year to year of the several brands, tables are given herewith showing the nitrogen, available phosphoric acid and potash percentages for the past five years of 182 of the 185 licensed brands. The guaranties printed in the tables are in all cases those for 1912 as well as for 1908-1911 with a single exception, which is footnoted. The * indicates that sulphate of potash was used as a source of potash.

These tables, containing the essentials of five years' inspection, ought to prove helpful in choosing fertilizers, particularly when they are bought early in the season.

ANALYSES OF LICENSED FERTILIZERS—1908-1912

BRAND	NITROGEN					AVAILABLE PHOSPHO ^O AC					POTASH							
	1908	1909	1910	1911	1912	Guar.	1908	1909	1910	1911	1912	Gua.	1908	1909	1910	1911	1912	Guar.
Grass and Lawn Top Dress.	5.40	4.23	4.56	4.16	3.59	3.91	6.90	5.94	5.80	5.94	6.00	5.	4.49	3.14	3.24	2.51	3.02	3.
Grass and Oats Fertilizer..	.....	.....	.....	.....	.....	.....	.....	12.13	11.78	11.02	11.30	11.	.....	1.96	2.14	2.08	2.66	3.
High Grade Ten Percent...	2.37	3.30	2.99	2.58	2.70	2.47	6.00	6.84	5.78	6.88	6.09	6.	9.88	10.09	10.20	10.17	10.43	10.
No. West Chal. Crop. Grow.	.....	1.18	1.46	1.16	1.19	1.03	.....	9.91	8.44	8.88	7.49	8	.....	2.36	2.39	2.20	2.46	3.
Spec. Grass and Garden....	.....	.....	.....	.....	8.42	8.45	.....	.....	.....	.....	5.85	6.25	.....	.....	.....	.....	9.78	8.35
XXX Phosphate & Potash	.....	.....	.....	.....	.....	.....	.....	.....	10.32	10.16	9.84	8.	.....	.....	10.59	8.71	9.82	8.
Bradley's Alkaline Bone ...	.....	.....	.....	.....	.....	.....	10.32	11.57	10.84	11.72	10.74	11.	1.91	2.20	2.52	2.44	2.46	3.
Bradley's Comp. Corn. Gr.	.....	.....	.....	.....	3.45	3.29	.....	.....	.....	.....	8.46	8.	.....	.....	.....	.....	8.34	7.
Bradley's Comp. Pot. Veg..	3.49	3.30	3.62	3.25	3.51	3.3	8.68	7.64	7.84	8.66	8.30	3.	6.73	6.90	6.90	7.03	6.80	7.
Bradley's Comp. 10 Perc't.	3.47	3.26	3.65	3.52	3.27	3.3	6.78	7.50	5.34	7.30	5.80	6.	10.25	9.99	10.09	10.26	10.56	10.
Bradley's Comp. Top Dress	.....	.....	.....	...	4.87	4.94	.....	.....	.....	.....	5.18	4.	.....	.....	.....	.....	7.31	6.
Bradley's Corn Phosphate	2.17	2.60	2.30	2.19	2.28	2.06	8.36	9.39	8.52	8.64	8.20	8.	1.90	2.17	1.91	1.59	2.18	1.5
Bradley's Eclipse Phos....	0.90	1.31	1.39	1.32	1.40	1.03	9.30	9.58	8.26	10.26	7.85	8.	2.12	2.48	2.74	2.28	2.54	3.
Bradley's Gn. Mt. Special	....	.....	2.14	1.86	1.91	1.65	.....	.....	9.26	9.02	8.56	8.	.....	...	5.10	5.60	5.25	6.
Bradley's H.G. Pot. & Root	.....	.....	2.46	2.31	1.92	1.65	.....	.....	8.96	8.94	8.22	8.	.....	.....	8.44	10.09	10.28	10.

*Potash in brands thus marked is largely if not entirely sulphate. †Contained 0.20 percent or more of mineral nitrogen.

ANALYSES OF LICENSED FERTILIZERS—1908-1912

BRAND	NITROGEN					AVAILABLE PHOSPHORIC ACID					POTASH							
	1908	1909	1910	1911	1912	Guar.	1908	1909	1910	1911	1912	Guar.	1908	1909	1910	1911	1912	Guar.
Bradley's Niagara Phos....	1.12	1.12	1.19	1.32	1.02	0.82	7.98	8.01	9.22	8.44	7.10	7.	1.45	1.60	2.26	1.62	1.61	1.
Bradley's Potato Fertilizer	1.98	2.17	2.30	2.41	2.32	2.06	8.30	9.42	9.00	9.08	8.36	8.	3.36	2.97	3.16	3.24	3.35	3.
Bradley's Potato Manure..	2.83	2.91	3.47	2.51	2.62	2.47	6.88	6.08	6.12	7.06	6.84	6.	6.78	4.98	7.88	4.93	5.67	5.
Bradley's Vermont.....	2.21	2.42	2.32	2.35	2.24	2.06	8.18	8.34	9.00	8.80	8.38	8.	3.11	3.09	3.35	3.46	3.40	3.
Bradley's XL Superphos...	2.95	2.46	2.86	2.74	2.75	2.47	9.08	9.24	9.98	9.96	8.80	9.	2.71	2.28	2.74	2.58	2.30	8.
Clark's Cove Bay State G.G.	2.14	2.32	2.21	2.24	2.34	2.06	8.38	7.98	9.20	8.44	8.38	8.	1.65	1.88	1.79	1.94	1.72	1.5
Clark's Cove King Philip...	1.26	1.26	1.26	1.25	1.09	1.03	8.38	8.34	8.98	8.04	8.15	8.	2.06	2.22	2.32	2.02	2.30	8.
Clark's Cove Potato Fert...	2.10	2.39	2.30	2.19	2.41	2.06	8.56	8.10	9.66	8.64	8.44	8.	3.50	3.27	3.33	3.33	3.70	3.
Cleveland Fertilizer.....	1.37	1.14	1.23	1.12	1.19	1.03	8.78	9.30	9.88	8.60	8.10	8.	2.20	2.24	2.19	2.11	2.59	8.
Cleveland Potato Phos.....	2.14	2.24	2.05	2.23	2.49	2.06	8.26	9.16	9.70	8.40	8.38	8.	3.21	3.47	3.47	3.12	3.47	3.
Cleveland Superphosphate.	2.17	2.24	2.25	2.28	2.41	2.06	8.08	8.66	9.44	8.46	8.34	8.	1.92	2.12	1.92	1.53	2.49	1.5
Crocker's Am. Corn Phos...	2.01	2.35	2.48	2.19	2.34	2.06	8.14	9.10	8.34	8.90	7.74	8.	2.25	1.90	1.80	1.69	1.70	1.5
Crocker's N. Rival Ammo..	1.16	1.16	1.42	1.11	1.26	1.03	8.82	9.34	8.56	7.94	8.01	8.	2.05	2.21	2.40	2.06	2.43	8.
Crocker's Pot., Hop & Tob.	2.05	2.28	2.34	2.46	2.26	2.06	7.68	9.09	9.10	9.08	8.12	8.	3.22	3.19	3.40	3.23	3.01	8.
Crocker's Special Potato....	3.33	3.75	3.67	3.55	3.41	3.3	6.06	7.58	5.66	6.72	6.76	6.	10.44	9.84	10.04	10.66	10.10	10.

*Potash in brands thus marked is largely if not entirely sulphate.

ANALYSES OF LIENSED FERTILIZERS—1902-1912

BRAND	NITROGEN						AVAILABLE PHOSPHO'IC ACID						POTASH					
	1908	1909	1910	1911	1912	Guar.	1908	1909	1910	1911	1912	Guar.	1908	1909	1910	1911	1912	Guar.
Cumberland Guano.....	.....	1.37	1.25	1.23	1.21	1.05	.....	8.70	10.04	8.80	8.82	8.	.....	1.93	2.27	2.18	2.47	8.
Cumberland Potato Fert...	1.95	2.24	2.48	2.36	2.42	2.06	8.66	9.24	8.80	8.24	8.00	8.	3.78	3.36	3.36	3.20	3.18	8.
Cumberland Superphos....	2.14	2.32	2.39	2.07	2.35	2.06	7.98	8.68	9.26	8.44	8.12	8.	1.82	2.32	1.69	1.54	1.86	1.5
Darling's Farm Favorite...	2.05	2.24	2.10	2.32	2.41	2.05	7.96	8.66	10.32	9.22	8.84	8.	3.01	3.17	3.50	3.22	3.05	8.
Darling's General Fert.....	.....	1.68	1.56	1.37	1.41	0.82	.....	7.58	8.05	7.42	6.76	8.	.....	4.18	3.33	3.15	3.78	4.
E. Ind. Complete Potato...	3.44	3.40	3.60	3.44	3.58	3.5	6.36	6.86	6.46	6.98	6.92	6.	9.87	10.18	10.20	10.08	10.43	10.
E. Ind. Harvest Home.....	1.12	1.26	1.32	0.96	1.21	1.05	8.09	9.28	8.76	8.96	8.16	8.	2.00	2.24	2.14	2.00	2.36	8.
E. Ind. Standard UnXID..	1.51	1.75	1.89	1.77	2.30	1.65	8.04	9.60	8.80	8.54	8.06	8.	2.24	2.95	2.59	2.33	4.78	8.
Great East. Garden Special	3.65	3.56	3.76	3.37	3.44	3.5	8.18	7.12	8.54	9.02	9.42	8.	7.26	7.63	7.39	7.47	7.48	7.
Great East. General Fert...	1.44	1.18	1.25	0.91	1.00	0.82	7.70	7.99	8.96	9.72	8.04	8.	5.09	4.05	3.92	3.95	4.90	4.
Great East. No. Corn Spec.	2.21	2.28	2.46	2.03	1.83	2.06	8.40	8.47	9.20	9.36	6.85	8.	1.89	1.75	1.88	1.76	1.92	1.5
Great East. Potato Manure	2.17	2.17	2.23	2.42	2.17	2.06	8.20	8.61	9.42	8.86	8.58	8.	3.20	3.04	3.18	3.20	3.17	8.
Pac. Gu. Co.'s Nobesque Gu.	1.37	1.11	1.23	1.19	1.19	1.05	8.74	9.56	9.24	8.74	7.48	8.	2.02	2.02	2.15	2.26	2.64	8.
Pac. Gu. Co.'s Potato Spec.	2.07	2.24	2.16	2.30	2.20	2.06	8.28	8.14	9.50	8.96	8.07	8.	3.22	3.34	3.38	3.16	3.46	8.
Pac. Gu. Co.'s Sol. Pac. Gu.	2.14	2.10	2.46	2.21	2.00	2.06	8.70	8.00	9.40	8.64	7.45	8.	1.98	1.77	1.95	1.62	2.19	1.5

*Potash in brands thus marked is largely if not entirely sulphate.

ANALYSES OF LICENSED FERTILIZERS—1908-1912

BRAND	NITROGEN					AVAILABLE PHOSPHO'IC ACID					POTASH							
	1908	1909	1910	1911	1912	Guar	1908	1909	1910	1911	1912	Guar	1908	1909	1910	1911	1912	Guar
Quinnipiac Climax Phos....	1.37	1.35	1.33	0.97	1.25	1.03	8.84	8.38	7.82	7.92	8.42	8.	1.99	2.36	2.58	2.09	2.25	8.
Quinnipiac Corn Manure...	2.05	2.17	2.36	2.23	2.32	2.06	8.18	9.03	8.38	8.58	8.32	8.	2.08	2.18	1.70	1.54	1.86	1.5
Quinnipiac Market Garden	3.40	3.39	3.53	3.32	3.49	3.3	8.03	8.26	8.16	8.38	8.44	8.	6.96	7.72	6.87	7.04	6.85	7.
Quinnipiac Potato Phos....	2.07	2.24	2.28	2.17	2.30	2.06	8.50	9.09	8.92	8.88	8.74	8.	3.28	3.08	3.44	2.90	3.06	8.
Read's Farmers' Friend....	1.81	2.28	2.16	2.26	2.37	2.06	8.30	8.78	9.58	8.76	8.38	8.	3.62	3.18	3.58	3.16	3.04	8.
Read's H. G. F.'s Friend...	3.12	3.32	3.54	3.32	3.30	3.3	6.30	6.85	5.25	7.32	6.58	6.	10.47	10.06	10.67	10.56	9.93	10.
Read's Leader Bl. and Bone	1.19	1.12	1.40	1.32	1.00	0.88	8.28	7.38	7.90	7.64	7.54	7.	1.32	1.02	2.53	1.44	4.45	1.
Read's Potato Manure	.....	.....	2.80	2.53	2.78	2.47	.....	.....	5.98	6.82	6.43	6.	.....	.....	9.76	10.26	9.84	10.
Read's Prac. Potato Spec'l	1.51	1.04	1.81	1.30	1.11	0.82	7.24	7.44	8.72	5.36	4.45	4.	10.03	8.08	9.21	6.46	7.70	8.
Read's Standard Superphos	1.47	1.16	1.41	1.32	1.09	0.82	7.67	8.20	8.08	8.68	7.82	8.	5.07	4.09	4.61	3.84	4.43	4.
Read's Sure Catch Fert.....	.....	.....	.....	....	.....	.....	10.06	11.99	11.24	11.06	10.52	10.	1.57	2.10	2.02	2.99	2.73	8.
Tucker's Imperial all Crops	1.07	1.30	1.47	1.14	1.11	1.03	9.66	9.19	9.46	8.34	8.12	8.	2.22	2.59	2.24	2.03	2.42	8.
Tucker's Imperial Corn.....	0.88	1.33	1.23	1.23	1.07	1.03	9.56	8.64	9.04	8.06	8.38	8.	2.17	2.04	2.08	2.30	2.40	8.
Tucker's Imperial Potato...	1.12	1.47	1.25	1.07	1.07	1.03	9.70	8.54	9.16	8.18	8.57	8.	2.31	2.30	2.04	2.00	2.36	8.
W. & Cl. Am. Bone Phos...	.....	.....	.....	2.64	2.76	2.47	.....	.....	.....	9.58	8.62	9	.....	.....	.....	2.36	2.06	8.

*Potash in brands thus marked is largely if not entirely sulphate.

ANALYSES OF LICENSED FERTILIZERS—1908-1912

BRAND	NITROGEN					AVAILABLE PHOSPHORIC ACID					POTASH							
	1908	1909	1910	1911	1912	Guar	1908	1909	1910	1911	1912	Guar	1908	1909	1910	1911	1912	Guar
W. & Cl. Am. Corn Phos...	1.96	2.14	2.35	2.24	2.32	2.06	8.48	8.85	9.84	9.24	7.00	8.	1.79	2.09	2.46	1.82	1.91	1.8
W. & Cl. Am. H. G. Sp. Pot	3.44	3.35	3.60	3.34	3.58	3.3	8.01	8.12	7.70	8.48	8.36	8.	7.26	6.77	6.72	7.81	8.10	7.
W. & Cl. Am. Potato Man.	2.10	2.28	2.23	2.24	2.08	2.06	8.16	9.16	10.20	8.92	8.19	8.	3.15	3.38	3.66	3.15	3.05	3.
W & Cl. Potato Phos.	2.74	2.79	2.93	2.60	2.37	2.5	7.28	6.37	8.01	6.92	6.19	6.	5.60	4.84	5.55	5.08	5.16	5.
W. & Cl. Prolific Crop Pro.	1.37	1.19	1.42	1.09	1.12	0.82	8.14	7.50	7.82	7.82	7.54	7.	1.25	1.67	2.37	1.15	1.50	1.
W. & Cl. Royal Bone Phos.	1.33	1.26	1.35	1.18	1.18	1.03	8.80	9.09	8.77	8.26	7.75	8.	1.95	2.03	2.06	2.05	2.00	2.
Armour's Banner Brand....	.....	.....	.....	.....	.....	.....	.....	11.80	9.82	10.16	10.96	10.	.....	8.08	8.08	7.89	8.61	8.
Armour's Bean and Farm..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8.28	8.	.....	.....	.....	.....	4.55	4.
Armour's Complete Man....	.....	3.21	3.66	3.40	3.60	3.3	.....	6.52	6.60	6.60	6.50	6.	.....	10.14	10.44	9.53	10.18	10.
Armour's Fruit & Root Cp.	.....	1.28	1.85	1.84	1.87	1.65	.....	8.74	8.42	8.18	7.94	8.	.....	5.16	5.99	5.02	5.66	5.
Armour's High Gd. Potato.	.....	1.86	1.77	1.95	1.84	1.65	.....	9.84	8.14	8.68	8.20	8.	.....	10.35	9.80	9.79	11.10	10.
Armour's Trucker Special..	.....	.....	.....	.....	3.25	3.3	.....	.....	.....	.....	7.34	6.	.....	.....	.....	.....	9.80	10.
Bowker's Corn Phosphate..	1.61	1.79	2.12	1.77	2.02	1.66	8.54	8.10	9.20	8.56	8.30	8.	2.15	2.29	2.14	2.16	2.18	2.
Bowker's Early Potato	3.58	.....	3.56	3.44	3.56	3.29	8.28	.....	8.36	8.66	8.68	8.	6.70	.....	6.89	7.56	7.06	7.
Bowker's Hill and Drill....	2.86	2.74	2.79	2.69	2.42	2.47	9.44	9.90	9.24	10.14	9.72	9.	2.68	2.04	2.61	2.32	2.45	2.

*Potash in brands thus marked is largely if not entirely sulphate

ANALYSES OF LICENSED FERTILIZERS—1908-1912

BRAND	NITROGEN					AVAILABLE PHOSPHORIC ACID					POTASH							
	1908	1909	1910	1911	1912	Guar.	1908	1909	1910	1911	1912	Guar.	1908	1909	1910	1911	1912	Guar.
Bowker's Market Garden...	2.77	2.49	2.67	2.58	2.67	2.47	6.66	5.74	8.12	6.90	6.84	6.	9.85	11.19	9.81	9.96	10.29	10.
Bowker's Potash Bone.....	1.12	1.14	1.46	1.00	1.05	0.82	8.76	9.08	8.70	7.94	6.88	6.	1.93	2.26	2.20	2.22	3.01	2.
Bowker's Potash or Staple.	1.30	1.25	1.35	1.04	1.04	0.83	8.98	9.20	9.18	8.64	7.94	2.	3.58	4.80	3.38	3.37	4.99	2.
Bowker's Pot. and Veg. F.	2.32	2.67	2.81	2.62	2.39	2.47	8.42	9.22	8.96	9.40	7.74	2.	4.57	3.84	5.10	5.52	4.51	4.
Bowker's Pot. and Veg. P.	1.65	1.79	2.19	2.02	2.00	1.65	8.70	8.03	9.20	8.94	8.68	2.	2.19	2.24	2.34	2.07	2.14	2.
Bowker's Sol. Pot. Phos....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.46	10 10 10.	.....	.....	.....	.....	7.01	8.00	2.
Bowker's Square Brand....	2.09	1.98	1.97	1.62	2.07	1.65	8.22	7.85	9.56	7.28	7.52	6.	2.33	1.96	2.28	2.04	2.28	2.
Bowker's Stkbg. Corn M.	3.55	3.68	3.53	3.43	3.22	3.29	8.28	8.75	10.33	10.16	10.37	10.	7.01	7.04	7.35	7.28	6.94	7.
Bowker's Stkbg. Pot. M.	3.24	3.40	3.44	3.39	3.25	3.29	6.14	6.90	6.96	7.16	6.18	6.	10.27	9.98	10.08	10.77	10.16	10.
Bowker's Stkbg. Sd. Down	.....	.....	.....	2.69	2.77	2.47	.....	.....	.....	7.02	10.62	6.	.....	.....	.....	10.55	7.62	10.
Bowker's Stkbg. Top Dr.	4.91	4.77	5.21	5.11	5.18	4.93	4.44	7.77	5.32	4.70	4.12	4.	7.85	6.60	6.05	6.06	5.90	6.
Bowker's Super with P't'sh	.....	.....	.....	.....	.....	.....	9.93	11.34	11.68	10.50	11.40	10.	1.50	1.80	2.32	2.82	3.23	2.
Bowker's Sure Crop Phos..	1.16	1.08	1.40	1.05	1.06	0.82	9.06	9.44	9.96	8.96	8.01	2.	2.02	2.37	2.18	2.17	2.01	2.
Bowker's Vt. Grange Ch..	2.17	2.32	2.18	2.44	2.18	2.06	8.02	8.30	9.88	9.12	8.00	2.	3.05	3.24	3.52	3.05	3.08	2.
Bromley's Banner Brand...			3.78	3.51	3.74	3.29			8.00	8.76	8.28	2.			9.34	9.09	9.90	2.

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ANALYSES OF LICENSED FERTILIZERS—1908-1912

BRAND	NITROGEN					AVAILABLE PHOSPHO' O ACID					POTASH								
	1908	1909	1910	1911	1912	Guar.	1908	1909	1910	1911	1912	Guar.	1908	1909	1910	1911	1912	Guar.	
Bromley's Corn and Potato	.....	.....	1.35	1.56	1.66	1.83	.....	.....	9.84	8.78	8.84	8.6	.....	.....	2.90	2.96	3.14	8.6	
Bromley's Grass & Grain..	.....	.....	.....	.....	.....	.....	.....	.....	9.94	10.40	10.24	10.	.....	.....	2.07	2.46	2.58	8.	
Bromley's Gr. Mt. Brand..	....	.....	1.37	1.74	1.70	1.83	.....	.....	8.88	7.48	9.08	8.	.....	.....	5.23	5.59	6.04	6.	
Bromley's Potato Special..	.....	.....	2.05	1.72	1.89	1.66	.....	.....	8.26	8.36	8.26	8.	.....	.....	10.35	9.84	9.64	10.	
Bromley's Spec. Corn Fert	.....	.....	0.93	1.14	1.00	0.88	.....	.....	7.84	8.24	7.26	7.5	.....	.....	3.04	3.28	3.47	3.	
Bromley's Spec. Pot. Fert.	.....	.....	0.95	1.18	1.00	0.88	.....	.....	8.29	8.12	7.42	7.5	.....	.....	3.40	3.27	3.51	3.	
Buff. F. Co. Celery & Pot..	1.63	1.65	1.93	2.05	1.90	1.64	7.71	8.08	8.14	8.94	9.32	8.	10.45	10.64	10.86	9.81	9.71	10.	
Buff. F. Co. Ex. Phos. & Pot.									10.78	10.26	10.38	10.74	10.		6.95	8.04	8.04	8.00	8.
Buff. F. Co. Farm. Choice..	1.09	1.19	1.25	1.11	1.14	0.88	8.48	9.88	8.46	8.44	8.06	8.	5.02	4.72	4.93	4.93	5.16	6.	
Buff. F. Co. Fish Guano....	1.26	1.12	1.09	.....	1.22	0.88	9.28	9.69	9.26	.....	9.05	9.	3.25	1.89	2.02	.....	4.04	2.	
Buff. F. Co. General Crop..	.....	.....	.....	.....	.....	..	10.77	9.62	8.72	8.69	10.18	9.	5.15	3.02	3.34	3.36	3.64	3.	
Buff. F. Co. High Gr'd Man	.....	.....	3.51	3.18	3.28	3.88	.....	.....	7.58	8.12	7.64	7.	.....	.....	9.58	10.08	10.82	10.	
Buff. F. Co. New Eng. Spec.	1.93	1.75	2.00	1.91	2.05	1.64	8.52	9.60	9.69	9.84	9.44	9.	4.59	6.01	4.90	5.51	5.91	6.	
Burl. R. Co. Animal Brand	2.95	2.81	2.55	2.48	2.56	2.	5.32	4.41	5.80	5.30	5.82	4.	4.50	4.13	4.58	5.19	4.50	4.	
Burl. R. C. Grain Fert.....					1.23	1.					7.78	7.					4.13	4.	

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ANALYSES OF LICENSED FERTILIZERS—1908-1912

BRAND	NITROGEN					AVAILABLE PHOSPHO'IC ACID					POTASH							
	1908	1909	1910	1911	1912	Guar	1908	1909	1910	1911	1912	Guar	1908	1909	1910	1911	1912	Guar
Burl. R. Co. Spec. Potato..	2.95	2.67	2.77	2.58	2.56	2.47	5.06	3.65	4.14	7.02	5.72	5.	7.34	6.62	6.96	6.52	6.54	6.
Burl. R. Co. Vegetable.....	.....	.....	.....	.....	2.49	2.48	.....	.....	.....	.....	7.43	7.	.....	.....	.....	.....	10.96	10.
Coe-Mort. Col. Corn & Pot.	1.26	1.26	1.49	1.50	1.46	1.88	8.05	8.96	9.24	8.40	8.35	8.5	2.43	2.56	3.40	2.67	3.50	2.5
Coe-Mort. Ext. Spec. Pot...	.....	.....	1.58	1.79	1.97	1.66	.....	.....	7.98	7.97	8.45	8.	.....	.....	11.48	9.38	9.93	10.
Coe-Mort Fam Pr Gr. & Gr	.....	.....	.....	.....	.....	.....	11.18	12.18	9.78	10.00	11.30	10.	1.64	1.49	2.02	2.06	2.54	2.
Coe-Mort. Gold Brand.....	2.42	2.76	2.50	2.58	2.50	2.4	8.05	8.33	8.06	7.92	8.72	8.	5.67	5.69	6.76	5.89	6.58	6.
Coe-Mort. H. G. A. B. Super	2.03	2.17	1.93	2.09	1.91	1.85	9.74	10.10	8.36	8.10	8.90	8.	2.84	3.22	3.30	3.54	3.39	3.
Coe-Mort. N.E. Corn & Pot	1.19	1.15	1.21	1.10	1.00	0.82	8.84	8.45	7.96	8.24	7.40	7.5	2.84	2.74	3.08	2.95	3.62	3.
Coe-Mort. Stand. Potato ...	.....	.....	.....	3.25	3.46	3.3	.....	.....	.....	6.06	6.32	6.	.....	.....	.....	10.22	10.57	10.
Essex A 1 Superphos.....	1.14	1.70	1.40	1.37	1.37	1.8	8.42	7.68	7.28	7.50	6.94	7.	2.13	2.76	2.56	2.25	2.44	2.
Essex Comp. Corn, etc.....	3.13	3.13	3.27	3.63	3.32	3.28	6.10	6.08	6.19	6.90	6.16	6.	10.44	11.91	10.70	9.85	10.07	10.
Essex Comp. Potatoes, etc.,	3.44	3.30	3.29	3.56	3.51	3.28	5.58	6.70	7.01	7.40	6.76	6.	10.80	10.17	10.10	10.14	9.96	10.
Essex Grain, Grass & Pot..	1.02	1.13	1.14	0.97	0.93	0.82	9.08	8.27	8.60	8.68	7.77	8.	4.46	4.51	3.94	4.10	4.39	4.
Essex Mar. Garden & Pot..	1.98	1.95	2.42	2.13	2.16	2.	7.93	8.08	8.11	8.54	8.54	8.	5.55	5.48	5.47	5.14	5.44	5.
Essex XXX Fish & Pot....	2.10	2.21	2.32	2.43	2.18	2.	9.14	8.30	8.43	8.56	8.30	8.	3.04	3.16	3.20	3.36	3.53	3.

*Potash in brands thus marked is largely if not entirely sulphate.

ANALYSES OF LICENSED FERTILIZERS—1908-1912

BRAND	NITROGEN					AVAILABLE PHOSPHO ^a ACID					POTASH							
	1908	1909	1910	1911	1912	Guar.	1908	1909	1910	1911	1912	Guar.	1908	1909	1910	1911	1912	Guar.
Hubbard Royal Ensign.....	.....	.....	.....	.....	2.23	2.46	.....	.....	.....	.....	.....	8.30	8.	.....	.....	.....	4.80	4.
Lister's G. Brand.....	0.98	1.12	1.26	1.00	1.10	0.82	8.16	8.10	8.74	8.56	7.67	8.	3.94	4.17	4.68	4.01	4.48	4.
Lister's Grass & Grain Fert	.....	.....	.....	.....	.....	.....	.....	.....	10.24	10.52	10.12	10.	.....	.....	2.21	2.22	3.29	2.
Lister's Grass and Oats.....	0.95	1.05	1.30	.....	1.04	0.82	8.05	8.27	8.38	.....	8.44	8.	3.70	4.90	4.33	.....	4.35	4.
Lister's Oneida Special.....	0.98	1.04	1.21	1.09	1.41	0.83	7.34	7.82	7.66	7.44	7.16	7.	1.33	1.50	1.57	1.07	1.46	1.
Lister's Potato Manure.....	3.61	3.79	3.64	3.46	3.46	3.29	8.75	8.46	8.28	8.36	8.74	8.	7.26	7.44	6.43	7.90	7.70	7.
Lister's Special Corn Fert..	1.79	1.89	1.51	1.47	1.30	1.23	8.55	8.10	8.40	8.70	8.88	8.	3.49	3.30	3.48	3.36	3.32	3.
Lister's Special Pot. Fert...	1.89	1.88	2.23	1.97	1.93	1.65	9.07	7.75	8.10	8.22	7.66	8.	3.35	3.78	3.51	3.34	3.56	3.
Lister's Special 10% Potato	1.79	1.91	2.00	2.05	1.69	1.65	9.80	8.61	7.92	8.44	8.68	8.	10.41	10.93	11.02	10.08	10.38	10.
Lister's Success Fertilizer..	1.30	1.44	1.37	1.56	1.53	1.23	9.42	9.58	9.40	9.60	9.14	9.	2.24	2.14	2.55	2.28	2.24	2.
Nat. F. Co. Chit. Am. Bone	.....	.....	.....	.....	1.68	1.65	.....	.....	.....	.....	7.88	8.	.....	.....	.....	.....	2.31	2.
Nat. F. Co. Chit. Com. Root	.....	.....	.....	.....	3.72	3.29	.....	.....	.....	.....	8.88	8.	.....	.....	.....	.....	7.15	6.
Nat. F. Co. Chit. Eureka...	.....	.....	.....	.....	2.56	2.47	.....	.....	.....	.....	6.88	6.	.....	.....	.....	.....	9.60	10.
Nat. F. Co. Chit. H. G. Top Dr.	.....	.....	.....	.....	7.83	8.43	.....	.....	.....	.....	5.78	6.25	.....	.....	.....	.....	8.34	8.
Nat. F. Co. Chit. Potato....	.....	.....	.....	.....	2.33	2.05	.....	.....	.....	.....	8.58	8.	.....	.....	.....	.....	6.97	6.
Nat. F. Co. Universal..	.....	.....	.....	.....	1.02	0.82	.....	.....	.....	.....	8.14	8.	.....	.....	.....	.....	1.88	5.

^a Potash in brands thus marked is largely if not entirely sulphate (a) Nitrogen guaranty, 1.65 per cent.

ANALYSES OF LICENSED FERTILIZERS—1908-1912

BRAND	NITROGEN				AVAILABLE PHOSPHORIC ACID				POTASH			
	1908	1909	1910	1911	1912	Guar	1908	1909	1910	1911	1912	Guar
N. E. F. Co. Comp. Manure...	.....	.....	3.86	3.44	3.51	\$ 2.8	.....	.....	.....	9.83	10.26	10.37 10.
N. E. F. Co., Corn & Grain	1.23	1.55	1.58	1.47	1.31	1.23	7.06	7.48	7.66	7.74	7.68	7.
N. E. F. Co., Corn Phos...	1.84	1.74	1.88	1.93	1.86	1.64	8.00	8.68	8.62	8.48	8.70	8.
N. E. F. Co. Peerless..	0.98	0.98	1.00	0.86	1.11	0.82	6.89	8.00	7.34	7.46	7.48	7.
N. E. F. Co. Potato Fert...	1.89	1.86	1.88	1.70	1.83	1.64	7.12	6.99	7.46	7.30	6.96	7.
N. E. F. Co., Potato Grow.	.....	.....	.....	.....	2.84	\$ 4.6	.....	.....	.....	.....	.....	10 34 10.
N. E. F. Co. Superphos....	.....	.....	.....	2.67	2.49	\$ 4.6	.....	.....	.....	.....	4.26	4.31 4.
P. & P. Co.'s Corn & Gr. Ft	.....	.....	1.09	1.09	1.05	0.82	.....	.....	8.40	8.98	8.31	8.
P. P. Co.'s Plym'h Rock...	2.49	2.67	2.44	2.65	2.67	\$ 4.7	8.20	7.81	7.80	9.18	8.61	8.
P. & P. Co.'s Potato Fert...	1.89	2.83	1.91	1.77	1.77	1.66	6.04	7.19	6.64	6.72	7.57	6.
P. & P. Co.'s Pot. Grower..	2.49	2.57	2.81	2.66	2.74	\$ 4.6	6.26	6.42	6.32	6.38	6.81	6.
Read B. F. Co. All Crops..	.....	.....	.....	.....	1.65	1.64	.....	.....	.....	.....	6.74	7.
Read B. F. Co. Never Fail..	...	.....	.....	.....	0.88	0.82	.....	.....	.....	.....	7.38	8.
Read B. F. Co. Prize Win..	.....	.....	.....	.....	2.55	\$ 4.7	.....	.....	.....	.....	9.02	7.
Read B. F. Co. Sp. Pot. & Tob'	.....	.....	.....	.....	1.00	0.82	.....	.....	.....	.....	6.44	8.

*Potash in brands thus marked is largely if not entirely sulphate. †Contained 0.20 percent or more of water soluble nitrogen, usually as nitrate of soda.

(d) Available phosphoric acid guaranty, 9 percent.

ANALYSES OF LICENSED FERTILIZERS—1908-1912

BRAND	NITROGEN					AVAILABLE PHOSPHO'IC ACID					POTASH							
	1908	1909	1910	1911	1912	Guar.	1908	1909	1910	1911	1912	Guar.	1908	1909	1910	1911	1912	Guar.
R. & H. Co.'s Compl. Phos	(1) 1.12	1.54	1.63	1.83	1.63	1.5	(1) 8.42	7.72	8.50	8.10	7.05	7.	(1) 4.03	6.10	5.96	5.49	6.06	5.
R. & H. Co.'s Grass & Gr...	3.05	3.30	2.59	2.37	2.30	2.2	7.12	8.06	10.24	9.75	7.38	6.5	10.83	11.10	12.86	11.81	11.95	12.
R.&H.Co.'s New Mkt. Gd..	.....	1.61	2.05	2.44	2.32	2.	.....	6.16	7.45	6.86	6.07	6.	.....	10.97	10.67	10.15	11.32	10.
R. & H. Co.'s Oats & Top Dr.	8.70	8.95	8.23	8.51	8.48	8.5	4.83	4.36	6.42	4.62	6.10	5.9	10.29	9.31	8.79	10.17	7.80	8.
R. & H. Co.'s Potato Phos.	2.24	2.03	2.17	2.14	2.23	2.	8.82	10.34	9.80	9.96	9.25	9.	6.10	5.77	5.48	6.13	6.47	5.
R. & H. Co.'s Sol.Co.G'ICp.	2.35	2.74	2.88	2.89	2.91	2.6	6.40	7.12	7.79	7.14	5.85	6.	9.14	8.94	8.72	8.81	9.44	8.
R. & H. Co.'s Sol. Potato...	4.95	5.42	5.30	5.14	5.14	5.	8.48	7.68	7.30	8.14	7.79	7.	6.50	5.60	5.84	5.71	6.25	5.
R. & H. Co.'s Sol. Tobacco	4.55	4.91	5.07	5.19	5.30	5.	8.04	6.18	7.62	7.20	8.42	7.	14.46	13.91	10.95	10.19	10.16	10.
Royster's Complete Potato	.....	.....	.....	.....	3.41	3.29	.....	.....	.....	.....	5.63	6.	.....	.....	.....	.....	10.46	10.
Royster's Gold Seal Pot....	.....	.....	.....	.....	2.00	1.65	.....	.....	.....	.....	8.02	8.	.....	.....	.....	.....	9.90	10.
Royster's Imperial Farm...	.....	.....	.....	.....	1.04	0.82	.....	.....	.....	.....	8.04	8.	.....	.....	.....	.....	5.04	4.
Sanborn's Grass & Grain...	.....	.....	.....	.....	5.51	5.15	.....	.....	.....	.....	7.58	4.	.....	.....	.....	.....	6.78	6.
Sanborn's Hill & Drill.....	.....	.....	.....	.....	3.09	2.5	.....	.....	.....	.....	6.98	7.	.....	.....	.....	.....	5.12	4.
Sanborn's Potato & Corn...	.....	.....	.....	.....	4.05	3.5	.....	.....	.....	.....	7.49	7.	.....	.....	.....	.....	8.02	8.
Sanderson's Atlantic Coast	.....	.....	2.63	2.21	2.02	1.67	.....	.....	5.28	5.34	4.82	4.	.....	.....	4.53	4.38	4.36	4.

*Potash in brands thus marked is largely if not entirely sulphate. †Contained 0.20 percent or more of water soluble nitrogen, usually as nitrate of soda. (1) Nitrogen guaranty, 1 percent; available phosphoric acid guaranty, 8 percent; potash guaranty, 3.5 percent.

ANALYSES OF LICENSED FERTILIZERS—1908-1912

BRAND	NITROGEN				AVAILABLE PHOSPHORIC ACID				POTASH			
	1908	1909	1910	1911	1912	guar	1908	1909	1910	1911	1912	Guar
Sanderson's Corn Superph.	.....	.....	2.41	2.28	1.84	1.67	.....	.....	.....	7.30	8.70	7.04
Sanderson's Potato Manure	.....	.....	1.84	2.28	2.14	1.67	.....	.....	.....	6.46	6.68	5.72
Sanderson's Special 10 %	.....	.....	2.67	3.33	2.88	2.47	.....	.....	.....	5.84	7.12	6.06
Swift's Lowell Animal.....	2.46	2.74	2.56	2.60	2.88	2.47	8.32	8.62	8.14	8.50	9.08	8.
Swift's Lowell Bone Ft.....	1.72	1.51	1.95	1.63	1.84	1.64	8.44	8.18	8.94	8.56	8.78	8.
Swift's Lowell Cereal.....	1.02	1.00	0.90	1.19	0.93	0.83	7.32	7.61	7.26	7.94	7.22	7.
Swift's Lowell Express.....	1.37	1.47	1.37	1.43	1.27	1.23	7.34	7.84	7.52	7.68	7.03	7.
Swift's Lowell Pot. Grow...	.....	.....	.....	.....	3.65	3.28	.....	.....	.....	.....	6.56	6.
Swift's Lowell Pot. Man....	1.74	1.89	1.81	1.84	1.75	1.64	7.78	7.48	6.86	7.16	7.88	7.
Swift's Lowell Pot. Phos....	2.70	2.50	2.49	2.58	2.65	2.46	7.66	8.26	8.48	8.60	8.64	8.
Swift's Lowell Spec. Corn....	.....	.....	.....	3.43	3.32	3.23	.....	.....	.....	8.56	8.28	8.
Swift's Lowell Spec. Grass.	.....	.....	.....	.....	4.16	4.1.	.....	.....	.....	.....	7.74	8.
Swift's Lowell Spec. Pot....	.....	.....	2.64	2.65	2.93	2.46	.....	.....	6.64	7.02	6.96	6.
Swift's Lowell Sterling	1.02	1.12	1.12	1.09	1.02	0.88	8.21	8.44	9.14	8.20	8.74	8.
Swift's Lowell Superior.....	3.86	3.89	4.03	3.79	3.63	3.69	7.60	7.38	7.30	7.52	8.40	7.
Swift's Lowell Veg. & Gr....					2.11	1.64					9.14	9.

*Potash in brands thus marked is largely if not entirely sulphate.

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UNIVERSITY OF VERMONT
AND STATE AGRICULTURAL COLLEGE

VERMONT AGRICULTURAL
EXPERIMENT STATION

BURLINGTON, VT.

BULLETIN NO. 167

JUNE, 1912

Micro-organisms of Maple Sap

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*In cooperation with Bu. An. Ind., U. S. Dept. Agr.

Esch.
Abstract
University of Vermont
1-27-34

BULLETIN 167: MICRO-ORGANISMS OF MAPLE SAP.

Part I. Micro-organisms Occurring in Maple Sap and their Influence on the Color, Flavor and Chemical Composition of Sirup.

By H. A. EDSON

Part II. Discussion of Physical and Chemical Data Secured on Maple Sirups Obtained from Saps Inoculated with Micro-organisms.

By C. H. JONES

Part III. Technical Description of Certain Bacteria Occurring in Maple Sap.

- A. Description of *Bacillus aceris* (n. sp.).**
- B. Brief Description of the Pink Cocci of Maple Sap.**
- C. The Green Fluorescent Bacteria Occurring in Maple Sap.**

By H. A. EDSON and C. W. CARPENTER

The completion of the studies reported in Part I and in Part III (A) of this bulletin was made possible through the courtesy of the Chief of the Bureau of Plant Industry of the United States Department of Agriculture. The author of those parts, the former station bacteriologist, when he withdrew from station employ to enter that of the Department, had not pursued the investigation far enough to warrant final publication. The Chief of the Bureau generously allowed him to continue his work after he had become connected with the Department during the succeeding sugar season, at intervals during the year, and for several months early in 1912 while preparing the matter for the press. Had it not been for this cordial cooperation, the matter could hardly have been brought to a successful issue; and the Station gratefully acknowledges its obligation for the courtesy.

J. L. HILLS, Director.

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PART I

MICRO-ORGANISMS OCCURRING IN MAPLE SAP AND THEIR INFLUENCE ON THE COLOR, FLAVOR AND CHEMICAL COMPOSITION OF SIRUP

By H. A. EDSON

INTRODUCTION

A preliminary contribution upon the work presented in this paper appeared in bulletin 151 (1910). Only the more important facts reported at that time are restated in the present paper, but quotations and repetitions stripped of details are introduced when essential to a clear and complete presentation. The problem is most satisfactorily introduced, however, by a somewhat lengthy quotation from the former paper, in which, for the information of any who may not be familiar with them, are included brief descriptions of the main facts of sap flow and of sugar making as practiced in Vermont.

"Late in March, in this section, evidences of coming spring appear. The nights are still cold and frosty but the days are genial and the temperature rises a few degrees above the freezing point. If, at this time, the trunk or limbs of certain species of the genus *Acer* are fresh wounded a sweet sap exudes. The Indians were familiar with this phenomenon before white men came; and had learned to collect, to concentrate and to make sugar from this sap. The early settlers¹ learned from them the essential steps which, in modified form, constitute the procedure followed in the maple sugar industry today."

"According to modern practice the tree is tapped by boring a half-inch hole 2 inches deep about 4 feet from the ground. A round, hollow spout or "spile" of wood or metal, upon which is suspended a bucket to catch the dripping sap, is driven into the hole. The sap flow is not continuous but is divided into short intermittent periods, technically termed 'runs.' It occurs only during the three or four weeks which immediately precede the unfolding of the leaf buds. Both its periodicity and

¹ Garden and Forest 4, p. 171.

its duration depend upon weather conditions. The sap is more likely to flow in the daytime than at night; and the more important runs are confined to what are spoken of as 'good sap days.' These occur only after the air temperature has remained below freezing for some time. If, following such a cold spell, the temperature rises materially above 32° F. a good run is likely to ensue. Excessive warmth and high winds check the flow. Freezing nights followed by moderately warm, cloudy days, and the absence of excessive sunshine and heavy winds, are the meteorological conditions which characterize the best sugar weather. So long as the air temperature remains essentially constant, whether warm or cold, little or no sap is obtained."

"The buckets in which the sap is caught are made of wood, tin, or galvanized iron; and, in the better works, are covered to keep out rain, snow and other foreign material. The sap is collected after each day's run and taken to the boiling house, technically known as the sugar house, where it is concentrated into sirup in large shallow pans over a roaring wood fire as rapidly as the capacity of the equipment will permit."

"Maple sap is a sweet liquid containing a varying amount, averaging from 2 to 3%, of sucrose, and, usually, traces of invert sugar. In addition to these carbohydrates it contains small amounts of proteids, of mineral matter, mainly lime and potash, and of acids, mainly malic acid. The sap of the earlier flows is water clear and transparent, and possesses a clean, sweet flavor. With the advance of the season, however, it undergoes a marked change. As the days grow warmer and night freezes are less severe and less frequent, the sap gradually becomes cloudy and discolored and unpleasant flavors develop. Such sap, while usually containing only the normal amount of acid, is popularly termed 'sour.' It rapidly deteriorates when stored even for a few hours. Several types of sour sap are recognized by sugar makers, to which the descriptive terms 'milky,' 'stringy,' 'red,' and, particularly, 'green' are commonly applied. Green sap is almost always secured just before the close of the season, when

the leaf buds are ready to open. It is popularly believed that the swelling of the buds, associated with the renewal of vegetative activity in the tissues of the tree, is accompanied by a change in the composition of the sap within the trunk; and that the alteration in color and flavor are manifestations of this change. The term 'buddy' is universally used to describe this sort of sap." (See Plate V).

"The sirup made from late runs is much inferior to that derived from the earlier flows. 'Last run' goods are often very dark in color and usually lack the delicate flavor possessed by the best sirups. Moreover, the quality of sirup varies markedly from year to year and these variations are seldom local in distribution. Such widespread fluctuations in quality are not accidental but of necessity must be associated with some fundamental cause or causes. It is conceivable that they may be related to weather conditions, either during the preceding summer or during the progress of the sugar season. It is known, moreover, that inferior products result from carelessness and lack of cleanliness in collecting and handling maple sap. Such procedures must occasion a great increase in the bacterial content of the sap, just as in dairying they entail serious bacterial contamination in milk. The proteid, carbohydrate and mineral contents of maple sap are sufficient to make it a fairly good medium for the development of bacterial life, provided suitable temperature relations are maintained; and the vital activities of large numbers of micro-organisms would presumably affect the flavor and quality of the sirup produced under such conditions."

"Reflection upon these facts strongly suggests the possibility that micro-organisms may be associated with the inferiority of the maple output in all the cases cited, or that, indeed, they may be the direct cause of the troubles. Inevitably they must be present in the sap and it is to be expected that they would be more abundant toward the close of the sugar season than earlier, because the warmer weather would favor their increasingly rapid development and multiplication. It is conceiv-

able that the 'off' seasons may prove to be those wherein conditions foster this microscopic life to an unusual degree. More favorable temperature relations, or longer periods of incubation, or both, in 'off' years and in the latter part of the season, might reasonably be expected to promote the multiplication of organisms in the tap-hole, spout and bucket, thus producing heavy initial inoculation of the sap. Uncleanly methods would certainly result in this condition, and in any case, storing, even for a short length of time, would serve to increase the troubles due to the vital activities of microscopic organisms, particularly if the temperature of the storage house was considerably above the freezing point, as is apt to be the case."

The experimental work upon which a report is submitted in these pages was undertaken in an effort to determine as far as might be possible the answers to the following questions: What is the cause of the deterioration of maple sap? Is it due to changes in composition occurring within the tissues of the tree as a result of the resumption of protoplasmic activities and vegetative vigor? Is it due to the action of micro-organisms in the sap after it leaves the vascular bundles of the trunk? Or is it to be attributed to a combination of these causes?

THE RELATION OF MICRO-ORGANISMS TO SPOILED MAPLE SAP

The early studies, previously reported, have shown that maple sap while in the vascular bundles of the tree is sterile, and that when drawn without contamination and stored under aseptic conditions it keeps perfectly for years, even with free access of air. Hence the changes in sap known as souring are not to be attributed to the action of enzymes present as natural ingredients or to other forms of auto-decomposition. Careful studies of the microscopic flora of spoiled sap have shown that micro-organisms are constantly associated with the process of souring.

In certain types of spoiled sap specific groups of organisms are likely to predominate, while in other types several of the

common forms may be found growing together in association. In addition to various common saprophytic bacteria, wild yeasts of several types, and green molds of the genera *Penicillium* and *Eurotium* are frequently met with, particularly towards the close of the season when the temperature becomes more favorable for their development. Green sap, for example, is associated with the presence of a group of bacteria characterized by green fluorescence and does not appear to be caused by the swelling of the buds to which it is so frequently related in time. In one type of stringy sap occasionally found, the only significant organism was one described in this paper as *Bacillus aceris* (new species), while in another type of stringy sap common at the close of the season, several species of bacteria, various wild yeasts, and molds of different genera occurred in association. Gray and red yeasts are commonly associated with bacteria in so-called red sap. Spore-bearing bacteria of the hay bacillus type were frequent in certain samples of milky sap examined, while the condition of other samples seemed attributable to the collective action of many different organisms.

The conclusion stated in the preliminary publication, that there is a causal relation between micro-organisms and sour sap and the resulting poor sirup, has been confirmed by all the examinations made during the progress of the work, and by the inoculation experiments to be reported later. A sequence of species was noted during the season of 1909, and discussed on page 494 of bulletin 151 where the following sentences occur: "The predominating organisms found during the early days of the sugar season belong to the yeast-like group, while bacteria were relatively few in numbers. As the season advanced these conditions were reversed." Subsequent studies have not confirmed this observation. For the past two years relatively few organisms of any kind have appeared on the plates early in the season, but as a rule bacteria have predominated, and in general yeast-like organisms have appeared in important numbers only after the season was well advanced.

THE NUMBER OF MICRO-ORGANISMS IN MAPLE SAP

During the first two seasons covered by these studies (1907- and 1908) no attempt was made to determine the bacterial count in maple sap of different types. Attention was rather directed to determining the predominating forms of micro-organisms present, and to securing cultures to be employed as a basis for the morphological and biochemical studies and for inoculation work, which have constituted the major portion of the problem. In connection with the field studies of the past three years, however, some attention has been given to collecting data on the number as well as the character of the micro-organisms present. The time devoted to this feature of the work was limited and the data secured is consequently more or less fragmentary, but it appears of sufficient importance to warrant presentation. The material examined was secured from several sugar places and at various intervals during the season.

For the purpose of enumeration the ordinary poured plate method with dilutions was employed. Two types of media were used. The first was ordinary nutrient agar; the other, a synthetic agar, less well adapted to the cultivation of bacteria than is the ordinary agar but suited to the development of yeasts and molds. It had the following composition:

Water	1000	parts
Dextrose	100.	"
Peptone	20.	"
Ammonium nitrate	2.5	"
Magnesium sulphate	5.	"
Potassium nitrate	2.5	"
Potassium phosphate	2.5	"
Calcium chlorid	0.1	"
Agar	15.0	"

It should be understood that the figures given in the tables immediately succeeding are only approximate and that in most cases they are probably below the maximum because of the fact that the dilutions employed were usually insufficient to prevent serious crowding on the plates. The blank spaces in the column headed "synthetic agar" may be taken as an indication that the sap in question was plated only on nutrient agar.

NUMBER OF ORGANISMS IN SOUR MAPLE SAP

The results obtained with various samples of sour sap plated at one or another time during the progress of the work are given below in tabular form. Some of the material plated was just beginning to show signs of clouding while in other cases the process was well advanced. In general the degree of decomposition and the number of organisms found bore a direct relation to each other.

As may be seen from the table the count obtained on nutrient agar varied from 320,000 to 141,420,000 per cc. Allowing an average size of 1 micron by 3 microns the organisms represent approximately one-third the volume of the most heavily infected sap.

TABLE 1. ORGANISMS PER CC. IN SOUR MAPLE SAP

No. ¹	Nutrient agar	Synthetic agar	No.	Nutrient agar	Synthetic agar
1	3,084,000	200,000	27	14,000,000	9,546,000
2	6,100,000	2,000	28	5,667,000	51,000
3	21,300,000	.....	29	4,225,000	636,000
4	6,300,000	13,000	30	19,500,000	.....
5	1,272,000	.....	31	23,000,000	15,000
6	2,785,000	.....	32	9,750,000	37,000
7	320,000	715,000	33	325,000	.....
8	2,000,000	30,000	34	4,875,000	.....
9	843,000	200,000	35	10,400,000	.....
10	975,000	175,000	36	43,875,000	.....
11	8,276,000	20,000	37	11,275,000	.....
12	1,950,000	1,300	38	56,250,000	.....
13	6,500,000	500,000	39	2,250,000	.....
14	19,092,000	.....	40	1,625,000	.....
15	1,357,000	3,000	41	12,350,000	10,500
16	1,909,000	254,500	42	3,262,500	407,000
17	1,751,000	.....	43	23,400,000	60,000
18	10,000,000	.....	44	29,250,000	65,000
19	88,200,000	.....	45	11,700,000	646,300
20	1,950,000	.....	46	9,480,000	.....
21	14,500,000	2,450,000	47	14,670,000	.....
22	8,850,000	10,000	48	6,500,000	.....
23	7,300,000	500	49	73,125,000	87,750,000
24	2,150,000	30,000	50	65,000,000	100,000
25	5,540,000	17,500	51	13,000,000	3,640,000
26	7,500,000	.....	52	141,420,000	.....

¹ This series, 1-52, is entirely distinct from the similarly numbered series later discussed on pages 351 to 365.

NUMBER OF ORGANISMS IN SWEET MAPLE SAP

In contrast to the figures in the preceding table the results obtained from plating several samples of normal sap are of interest. In some cases the sap to be analysed was gathered with unusual care in order to secure as light an infection as might be without special apparatus, while in other cases it was taken from the commercial supply and is representative of the ordinary sap of the orchard in which the work was done. These two classes of material are grouped in separate columns. The higher figures in the column headed "commercial sap" were obtained late in the season from material which was developing an unpleasant flavor and which clouded promptly when placed in storage for a few hours. In one of these cases (11) the count obtained is higher than that from many of the sour saps reported above, and in the other four (4, 5, 10, 12) it is very high.

TABLE 2. ORGANISMS PER CC. IN SWEET MAPLE SAP

Carefully collected sap			Commercial sap		
No.	Nutrient agar	Synthetic agar	No.	Nutrient agar	Synthetic agar
1	120	140	1	1,300	16
2	100	45	2	3,700	1,000
3	500	160	3	3,800	700
4	5	0	4	32,500	10,000
5	30	8	5	162,000	325,000
6	66	17	6	900	610
7	59	7	7	1,000	500
			8	140	140
			9	220	220
			10	66,600	44,000
			11	1,000,000	1,100
			12	200,000	.....
			13	2,600	2,700
			14	9,290	784

The influence of cleanliness upon the number of organisms developing in maple sap may be seen in the results obtained in the following experiments.

Several trees were tapped with care, precautions being taken to prevent the introduction of inert matter carrying micro-

organisms into the tap-hole. Sterile metal spouts and buckets were used and the covers employed were fastened to prevent blowing in the wind. The sap was gathered daily, and after each collection the buckets were thoroughly scalded in order to maintain practical sterility. The plates poured from sap obtained on March 26 and April 6 appear in table 3.

TABLE 3. ORGANISMS PER CC. IN SAP OBTAINED IN STERILIZED CONTAINERS

Date	Tree	Nutri- ent agar	Syn- thetic agar	Date	Tree	Nutri- ent agar	Syn- thetic agar
3/26/11	A	3		4/6/11	A	6	10
"	B	6		"	B	4	2
"	C	250		"	C	3	6
"	D	0		"	D	4	2
"	E	30		"	E	0	5
"	F	2		"	F	2	32

BACTERIAL CONTENT OF SAP OBTAINED UNDER SEPTIC CONDITIONS AS COMPARED WITH THAT OBTAINED UNDER ASEPTIC CONDITIONS

Trees which were running sour sap were retapped about 4 inches to one side of the old tap-hole. Sterile spouts and buckets were hung at the fresh wounds, while the sour spouts and buckets were allowed to remain undisturbed except that the sap was emptied from the old bucket at the time the clean one was hung at the fresh tap-hole. The sap was allowed to run from each spout for a few hours, after which samples were collected and plated. The results are tabulated below in table 4.

TABLE 4. ORGANISMS PER CC. IN SAP FROM FRESH AND FROM SOUR TAPHOLES

Tree	<i>Fresh tap</i>		<i>Sour tap</i>	
	Nutrient agar	Synthetic agar	Nutrient agar	Synthetic agar
G	5	0	73,125,000	87,750,000
H	8		4,875,000	
I	70		9,750,000	
J	12		3,250,000	
K	10		1,300,000	

INFLUENCE OF TAP-HOLE INFECTION UPON THE FLORA OF SAP

For the purpose of this series of experiments 6 trees were tapped with unusual precaution to avoid infection in the hole at the time of tapping. The spouts used were of galvanized iron and were thoroughly sterilized before using, but remained undisturbed and without protection, other than the bucket cover, during the season. Bright tin buckets provided with covers were used. They were thoroughly washed and scalded at frequent intervals, usually daily, in order to prevent the accumulation of organisms, which otherwise occurs in the buckets as the season advances. There was, of course, the usual opportunity for increasingly heavy contamination of the flowing sap by organisms developing in the tap-hole and spout. The interval between scalding the bucket and plating the sample varied somewhat with the temperature but was usually about five hours. The progress of infection is shown in table 5. It is interesting to note that most of the colonies developing in the sap from tree number 3 were of a single species. It seems probable that this organism was carried into the tap-hole at the time of tapping and became established there to the practical exclusion of other species.

TABLE 5. ORGANISMS FROM TAP-HOLE AND SPOUT PER CC. OF MAPLE SAP

Date	Tree	Nutri- ent agar	Syn- thetic agar	Date	Tree	Nutri- ent agar	Syn- thetic agar
3/20/10	1	1	4	3/25/10	1	2	2
"	2	4	0	"	2	4	12
"	3	940	680	"	3	12600	12600
"	4	2	2	"	4	2	6
"	5	4	4	"	5	7	3
"	6	50	1	"	6	11	10
3/22/10	1	2	2	4/4/10	1	1300	910
"	2	40	4	"	2	400	0
"	3	1170	1040	"	3	292500	300000
"	4	6	1	"	4	1300	0
"	5	10	3	"	5	100	2
"	6	4	2	"	6	1000	16

The figures given above indicate that in most cases the infection in tap-hole and spout is slight during the early part of

the season but that it becomes more serious as the spring advances. In the case of tree number 3, however, there is a gradual, constant increase in the infection from the very first.

INFLUENCE OF THE CONTAINER ON THE BACTERIAL FLORA

The influence of the container upon the bacterial flora of sap is strikingly illustrated by the following experiment. On March 22, 1910, the sap which had flowed from the 6 trees mentioned in the previous table during parts of March 21 and 22, was mixed together and plated. The number of organisms per cc. upon nutrient agar was 120, on synthetic agar, 140. Most of these were of the type characteristic of tree 3 as noted above. On the morning of March 23, old but sound wooden buckets previously used in the orchard were thoroughly washed and hung at the 6 trees. The sap was collected, mixed and plated on the afternoon of the next day. The counts on nutrient agar averaged 6,500,000, and on synthetic agar, 500,000. The temperature and general weather conditions during the four days covered by this experiment were essentially similar. That this increase of organisms was due to the buckets employed may be seen by reference to the bacterial count given in table 5 for March 25, when clean tin buckets were again employed. While the evidence goes to show that the initial infection from the tap-hole of tree 3 was greater on March 23 and 24 than on March 21 and 22, there is no indication that this was the case with the other trees. It should also be noted that the plates poured on March 24 contained no large proportion of colonies characteristic of the organism of tree 3, and that the quality of sirup obtained (number 67 page 372) was not characteristic of the organism in question; hence it would seem that the container must be regarded as the chief source of the increase. See Plates VI and VII.

GENERAL PLAN OF FIELD EXPERIMENTS

Having established the fact that large numbers of bacteria and other micro-organisms are constantly associated with spoiled

sap, it remained to determine the influence of these agents upon the quality of sirup. Several hundred pure cultures of the predominant organisms occurring in various types of spoiled sap were isolated and studied more or less critically. After their character had been roughly determined, certain ones were selected for the inoculation experiments to be described presently.

The Orange county sugar orchard in which the field experiments were carried out is situated upon a western slope but is exposed to north winds. The soil of the greater part of the place is wet, and the orchard has had the reputation of producing a grade of sirup of only medium standard both in flavor and color. See Plate I.

The general plan followed during the first season was to secure sap as free from bacteria as was feasible without sterilization, and to introduce a sufficiently heavy inoculation of the specific organism to produce an overgrowth of the introduced species. In some of the later series pasteurization was employed before inoculation, and during the last season fractional sterilization was attempted. Following inoculation, after a period of incubation, the saps were concentrated to sirups under uniform conditions. The sirups were placed in glass jars, sterilized, sealed and shipped to the station bacteriological laboratory at Burlington, where they were stored in the dark for later scoring as to color and flavor, and subjected to a complete chemical analysis. As suggested above, the details of handling the sap before and during incubation varied somewhat from time to time. The details of these variations will be explained with the discussion of the individual samples.

In addition to the inoculation experiments referred to, which were usually confined to the early runs of the season, an attempt was made to procure late run sap relatively free from infection, in order to compare it with material drawn at the same time from the same trees under ordinary conditions. For this purpose trees which had begun to run sour were selected and, without disturbing the original tap-hole, spile or bucket, another spout

was introduced into the tree about 4 inches to one side of the original wound. Great care was observed to secure for this tap-hole as entire freedom from infection as was possible without special apparatus, and sterile spouts and buckets were employed. At the time of retapping, the sap in the sour bucket was emptied but the receptacle was not washed. In this way two samples of sap were obtained from the same tree at the same time, one of which was relatively free from micro-organisms, while the other was heavily infected. These two saps were concentrated to sirup under practically identical conditions and submitted to the same subsequent treatment as were the other sirups. These experiments were intended to show whether the changes which have been demonstrated to occur in sap near the close of the season were due entirely to the action of foreign organisms, or whether they should be ascribed in part or in entirety to physiological changes within the tree.

METHOD OF SIRUP SCORING

At the close of each season the sirups which had been made during the preceding weeks were scored for flavor by a commercial expert who was entirely unfamiliar with their history. A series of numbered beakers of uniform appearance were placed on a table and each received a few ounces of the sirup corresponding in number to that of the beaker. The expert tasted the sirups and assigned each to its respective grade. After the entire series had been scored, and a record made of the results, the samples were rearranged in such a way as to insure the loss of their identity, except by the small number on each beaker, and the judge was asked to regrade them. In cases of special importance the samples were repeatedly disarranged and passed back to be regraded. Incredible as it may seem they were invariably placed in the grades originally assigned them and usually in the same relative position within the grades. Not a single instance of contradiction occurred among the entire 128 samples.¹

¹ The Station is under obligation to Mr. Otto Ludwig of Burlington for his invaluable and expert assistance.

Six grades of flavor were recognized, the last two of which were reserved for material possessing the characteristic flavor known to experienced sugar makers as "buddy." The term "buddy" as employed in this bulletin should be understood to designate that peculiar flavor which occurs only in sirup made from late run sap drawn after the buds have begun to open. Much of the material popularly spoken of as "buddy" does not possess this distinctive character, which is difficult to describe but is instantly recognized by one who has become familiar with it.

Number 1 sirups possess a very high degree of excellency.

Number 2 sirups are also excellent but are slightly inferior to number 1.

Number 3 sirups possess the characteristic maple flavor but, in addition, there is present an unpleasant taste which detracts from their value.

Number 4 sirups lack maple flavor, possess an unpleasant foreign taste to a marked degree, and are to be regarded as of very poor quality.

Number 5 applies to sirups which possess the "buddy" flavor but are otherwise excellent.

Number 6 sirups combine the "buddy" flavor with the other foreign flavors previously mentioned.

Sirups of grades 5 and 6 can be marketed only with difficulty, and cannot be added to higher grade sirups even in small amounts without rendering the entire mixture undesirable for table purposes. Number 4 sirup does not find a ready market for domestic use unless mixed with higher grade goods.

The sirups were also graded carefully according to color. The method employed for color determination is that suggested by Bryan. The colors consist of a series of twenty standards for the preparation of which Bryan gives the following directions.¹

¹U. S. Dept. Agr., Bu. Chem., Bul. 134, p. 15 (1911).

"The materials used are (1) pure glycerin and (2) a caramel solution, which is prepared as follows:

Heat 6 grams of pure sugar to 212° C. for one-half hour in a flat bottomed aluminum dish and dissolve the caramel formed in boiling water, evaporate to a small volume, and make up to 200 cc. with glycerin. The oven for caramelizing the sugar (fig. 1) is constructed as follows:

A and A' are heavy sheets of asbestos board 18 cm. (7 inches) square, A' being perforated near one edge by a hole for a cork supporting the thermometer d; b is a sheet-iron cylinder 15 cm. (6 inches) in diameter; c is a tin can 9 cm. ($3\frac{1}{2}$ inches) in diameter, which is filled with paraffin to within 1 cm. ($\frac{1}{2}$ inch) of the top. This can rests on the pipe-stem triangle e. The bath or oven is supported on a tripod and is heated by two burners. One burner is so adjusted as to keep the bath at 212° C.

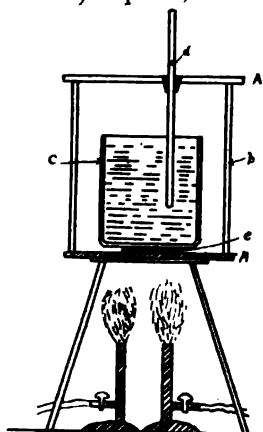


Fig. 1. Apparatus for preparation of standard caramel.

Bring the temperature of the oven up to 212° C., using both burners. Then remove the asbestos cover carrying the thermometer and place 6 grams of sugar in a flat-bottomed aluminum dish 7 cm. ($2\frac{3}{4}$ inches) in diameter and 1.5 cm. ($\frac{5}{8}$ inch) deep, and put it in the can containing the paraffin. Replace the cover at once and as soon as the temperature reaches 208° C. turn out one burner and keep the bath at 212° C. by carefully adjusting the other one. At the expiration of thirty minutes from the time the sugar was placed in the bath, dissolve in boiling water, and make up as described. The aluminum dish should not be less than 1.5 cm. ($\frac{5}{8}$ inch) deep, since the sugar melts before caramelizing and runs to one side of the dish, which, if too shallow, will tilt, fill with paraffin, and sink.

With the ingredients thus prepared, the scale of colors is made up by mixing as indicated in the following table:"

TABLE 6. AMOUNTS OF INGREDIENTS TO BE USED IN PREPARING SOLUTIONS FOR THE COLOR SCALE

Color number	Caramel solution, grams	Glycerin, grams
1	0.00	35.00
2	0.25	34.75
3	0.50	34.50
4	0.75	34.25
5	1.00	34.00
6	1.50	33.50
7	2.50	32.50
8	3.50	31.50
9	4.50	30.50
10	5.50	29.50
11	7.00	28.00
12	8.50	26.50
13	11.00	24.00
14	14.00	21.00
15	17.00	18.00
16	20.00	15.00
17	23.50	11.50
18	27.00	8.00
19	31.00	4.00
20	35.00	0.00

The standard colors were placed in screw-capped vials of perfectly clear glass having the same internal diameter. The samples to be examined were placed in similar vials and the colors compared by transmitted light.

For commercial purposes sirups are usually divided into three grades of color. The point of division between the standards fluctuates somewhat according to the locality and season. In a good season and in a locality where light sirups are produced, numbers up to and including 7 are regarded as first quality, while number 11 represents the dividing line between second quality and third. On the other hand in years or in localities characterized by dark sirup, the first eleven grades of color may be accepted as first quality, while number 15 becomes the dividing line between second and third qualities.

In addition to the rating for color and flavor a numerical score card was prepared in which color and flavor were both considered. In scoring, number 1 was ranked as 100, number 2 as 95, and so on, subtracting 5 from the score for each fall of

1 in grade. A number 20 sirup therefore received a value of 5 and anything darker than 20 a value of 0. A table of values is given below.

TABLE 7. VALUES ASSIGNED TO COLOR GRADES

Color	Value	Color	Value
1	100	11	50
2	95	12	45
3	90	13	40
4	85	14	35
5	80	15	30
6	75	16	25
7	70	17	20
8	65	18	15
9	60	19	10
10	55	20	5
		20+	0

In scoring for flavor certain samples were found which clearly were not sufficiently fine to be ranked as number 2 and at the same time were superior to number 3. Two fractional numbers were used to designate these groups. These were 2¹ and 2². Similarly one group was introduced between 3 and 4, which is designated as 3¹. In preparing the numerical score card the following table of values was employed:

TABLE 8. VALUES ASSIGNED TO FLAVOR GRADES

Flavor	Value	Flavor	Value	Flavor	Value
1	100	2 ²	80	4	50
2	90	3	75	5	20
2 ¹	85	3 ¹	65	6	0

The numerical score was obtained by multiplying by 5 the sum of the numerical values assigned for color and for flavor. The highest score theoretically possible is thus seen to be 1,000, but as a matter of fact no maple sirup has the color of clear glycerin so that a sirup of number 1 color is not to be expected, and the highest attainable score becomes 975.

INOCULATION EXPERIMENTS IN 1909

The first inoculations were made in 1909 and were carried out at a farm house some distance from the sugar woods where

most of the field studies were conducted. The sap was collected in clean tin buckets provided with japanned covers. The spouts used were of galvanized iron. Care was exercised to keep the buckets clean and sweet in order to avoid an accumulation of micro-organisms in the sap. The sap was gathered in clean tin cans such as are usually employed for transporting milk, and carried to the farm house in which the temporary laboratory was then established. It was divided into portions of sixteen quarts each and placed in new tin buckets provided with covers. Certain portions were reserved as controls and the remainder were inoculated by adding 70 cc. of a young actively growing culture of the specific organism selected. The controls were treated with similar amounts of sterile culture media. The inoculated samples were placed on a table and incubated for three days. The temperature variation during the respective incubation periods is shown in the accompanying graphs taken from the tracings made by a self-recording thermometer placed near the samples. The actual temperature of the sap was of course much more constant than that of the air. After an incubation period the various portions were made into sirup, each of the several saps being evaporated in a bright sugaring-off pan on a kitchen stove until condensed to a volume of about one quart. It was then transferred to a white, agate-ware basin, and evaporated as rapidly as possible until the proper concentration, as indicated by a thermometer, was reached. The process from cold sap to sirup, required about an hour and a half for its completion, except in the case of one sample when the time was intentionally prolonged. The samples made during the first season are those discussed in bulletin 151 as numbers 1 to 26 inclusive. The numbers used at that time, however, have not been retained in the present publication. Moreover the method of scoring employed in this article is not the one used in the former issue, a fact which explains any apparent lack of uniformity. The numbers used in the present bulletin and in the former one are given below in tabular form:

New number (Bul. 167)	Old number (Bul. 151)	New number (Bul. 167)	Old number (Bul. 151)
1	1	14	18
2	7	15	20
3	8	16	19
4	9	17	21
5	10	18	22
6	2	19	23
7	12	20	5
8	11	21	6
9	13	22	24
10	14	23	26
11	16	24	3
12	15	25	25
13	17	26	4

Since it was deemed important to conduct the inoculation experiments with sap from the first runs only, about 100 trees were tapped for experimental purposes as early as it seemed probable that any sap could be obtained.

DETAILED DISCUSSION OF SAMPLES

SERIES I: SIRUPS I TO 6

The sirups of this series were made from the first run of the season which occurred on March 24, 1909. It remained in the woods over night and was brought to the field laboratory the following morning and divided into six portions. Four of these were inoculated and two retained as controls. They were held for three days, the controls being kept at a temperature of from 0° to $+10^{\circ}$ C. The incubation temperature of the inoculated samples is indicated in the temperature graph (fig. 2).

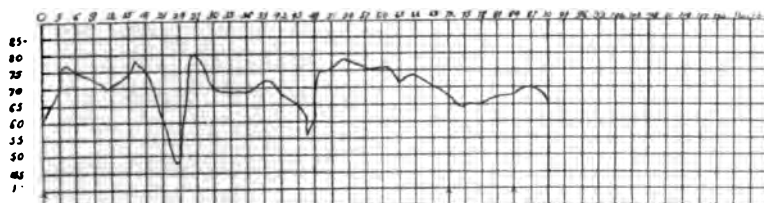


Fig. 2. Graph of incubation temperatures for series I; saps 1 to 6 inclusive. The arrow heads on next to the bottom line from left to right indicate respectively the time of inoculation, the time of evaporation of the first sample and the time of evaporation of the last sample.

The inoculated saps promptly developed a cloudy appearance and showed all the characteristics of so-called sour sap of the late runs. (See Plate V). The details of the various samples follow:

1. Number 1 was a control used to determine the influence of long boiling upon the quality of the product. The sap was held between three and four days at a temperature only slightly above freezing. At the end of that time it appeared to be as fresh and sweet as when brought from the woods. It was evaporated to sirup over so slow a fire that six hours were required to concentrate the 16 quarts of sap which constituted the sample. Calculated to a dry matter basis, the sirup contained 96.84% sucrose and 1.07% invert sugar. The color was 7, flavor 1, and grade 850; depreciation from control, (No. 6) color 1, flavor 0, and score 25.

2. Number 2 was inoculated with fluorescent organism XXXIII¹. It developed a cloudy appearance with the greenish cast characteristic of the so-called green sap. The sirup contained 96.79% sucrose and 1.55% invert sugar. The color was 14, flavor 4, and score 425; depreciation from control, color 8, flavor 3, and score 450.

3. Number 3 was inoculated with fluorescent organism XXXVI. It developed the characteristic green type of souring. The sirup contained 96.73% sucrose and 2.09% invert sugar. The color was 11, flavor 2, and score 700; depreciation from control, color 5, flavor 1, and score 175.

4. Number 4 was inoculated with fluorescent organism L, and developed a green type of souring. The sirup contained 96.54% sucrose and 1.56% invert sugar. The color was 9, flavor 2, and score 750; depreciation from control, color 3, flavor 1, and score 125.

5. Number 5 was inoculated with fluorescent organism L.III. It developed typical green souring. The sirup contained

¹ See Part III c. pages 521 to 599 for a description of the members of the fluorescent group employed in this and subsequent samples. Summaries of statistical data occur on pages 550-551, 598-599.



PLATE I.—A view in the experimental sugar orchard, Randolph, Vt. The covers shown above were not of the type used in the experimental work. (See page 344).



PLATE II.- Exterior view of field laboratory, located at the end of the "sugar house." (See page 359).

97.16% sucrose and 1.44% invert sugar. The color was 11, flavor 2, and score 700; depreciation from control, color 5, flavor 1, and score 175.

6. Number 6 was a control having exactly the same history as number 1, except that it was concentrated over a brisk fire under conditions which required less than 2 hours to reduce it to sirup. The sirup contained 95.41% sucrose and 0.97% invert sugar. The color was 6, flavor 1, and score 875.

SERIES 2: SIRUPS 7 TO 12

Following the run of March 24 no more sap was obtained until March 27, on which date a light run occurred and enough sap was secured for seven samples. Six of these were inoculated and handled under conditions similar to those described for series 1. The air temperature maintained during the incubation may be seen by referring to the graph (fig. 3). The seventh

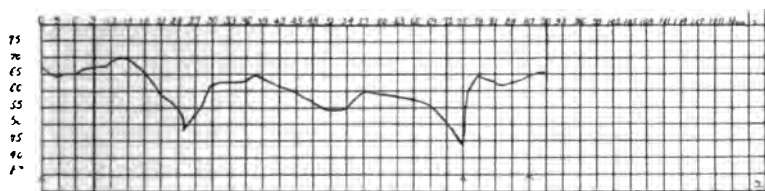


Fig. 3. Graph of incubation temperatures for series 2; saps 7 to 12 inclusive. The arrow heads on next to the bottom line from left to right indicate respectively the time of inoculation, the time of evaporation of the first sample and the time of evaporation of the last sample.

sample was reserved for a control, but, unfortunately, the glass jar containing the sirup was broken during sterilization and the sample was lost. From the notes made at the time of boiling it seems certain that the sirup was at least equal in quality to number 6 in the preceding series and probably slightly superior to it. The sirups of series 2 have therefore been referred to number 6 as a control. One of the saps of this series was titrated in cold solution against phenolphthalein with N/100 sodium hydroxide just before evaporation. The reaction is stated in percent of hundredth normal acid.

7. Number 7 was inoculated with fluorescent organism LVI. It developed typical green souring. The sirup contained 96.16% sucrose and 1.64% invert sugar. The color was 10, flavor 2, and score 750; depreciation from control, color 4, flavor 1, and score 150.

8. Number 8 was inoculated with fluorescent organism 5. A typical green sour sap developed. The sirup contained 97.14% sucrose and 1.15% invert sugar. The color was 10, flavor 2, and score 725; depreciation from control, color 4, flavor 1, and score 150.

9. Number 9 was inoculated with non-fluorescent organism XXVI. It developed a milky type of souring. The sirup contained 95.61% sucrose and 0.78% invert sugar. The color was 5, flavor 2, and score 850. The color was 1 point higher than the control, with a depreciation in flavor of 1, and in total score of 25.

10. Number 10 was inoculated with non-fluorescent organism XXX. It developed a very pronounced milky type of souring, accompanied by an unpleasant odor. The sirup contained 95.86% sucrose and 0.77% invert sugar. The color was 6, flavor 3, and score 750; depreciation from control, color 0, flavor 2, and score 125.

11. Number 11 was inoculated with *Bacillus aceris*, strain I,XXXVII, obtained from stringy sap. The sample developed a deep milky color and a yeasty odor and became stringy. The reaction was 170% N/100 acid. The vapor evolved during the concentration was extremely unpleasant, and was sufficiently noticeable to attract the attention of a sugar maker who was passing the house where the field laboratory was established. Although he was entirely unaware of the nature of the experiments, the steam borne to him through an open window elicited the remark, "It smells like the last of sugaring." The sirup contained 96.12% sucrose and 1.72% invert sugar. The color was 7, flavor 4, and score 600; depreciation from control, color 1, flavor 3, and score 275.

12. Number 12 was inoculated with non-fluorescent organism I, obtained from stringy peas. A milky type of souring developed. The sirup contained 95.71% sucrose and 2.23% invert sugar. The color was 6, flavor 3, and score 750; depreciation from control, color 0, flavor 2, and score 125.

SERIES 3: SIRUPS 13 TO 20

The sap for this series was secured April 1 and handled in the manner described for the two preceding series. The temperature of incubation may be seen by referring to the graph (fig. 4).

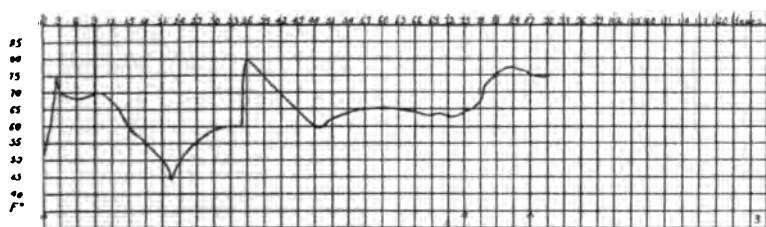


Fig. 4. Graph of incubation temperatures for series 3 ; saps 13 to 20 inclusive. The arrow heads on next to the bottom line from left to right indicate respectively the time of inoculation, the time of evaporation of the first sample and the time of evaporation of the last sample.

13. Number 13 was inoculated with gray yeast 24. A mixture of organisms developed. Apparently the fluorescent bacteria naturally present in the sap were not held in check by the yeasts, and the product seemed to be the results of the combined action of yeasts and bacteria. The sirup contained 93.34% sucrose and 2.53% invert sugar. The color was 7, flavor 2, and score 800; depreciation from control, color 1, flavor 1, and score 75.

14. Number 14 was inoculated with red yeast 25. A mixture of organisms developed as was the case with the previous sample. The reaction was 9% N/100 acid. The sirup contained 95.30% sucrose and 3.01% invert sugar. The color was 10, flavor 2, and score 725; depreciation from control, color 1, flavor 1, and score 150.

15. Number 15 was inoculated with red yeast LXII and incubated for 3 days. As with other samples previously reported where yeasts were employed a mixture of organisms developed. The reaction was 5% N/100 acid. The sirup contained 93.26% sucrose and 2.98% invert sugar. The color was 8, flavor 2, and score 775; depreciation from control, color 2, flavor 1, and score 100.

16. Number 16 was inoculated with green mold LXIV. The bacteria naturally present developed in conjunction with the mold and the sample had the appearance characteristic of the green type of souring, but it was evident from the tufts of mycelium present that the mold had made good growth. The reaction was 8.2% N/100 acid. The sirup contained 95.73% sucrose and 2.61% invert sugar. The color was 10, flavor 4, and score 525; depreciation from control, color 4, flavor 3, and score 350.

17. Number 17 was inoculated with green mold LXXV. A mixed infection resulted. The reaction was 8% N/100 acid. The sirup contained 92.76% sucrose and 3.47% invert sugar. The color was 10, flavor 2, and score 725; depreciation from control, color 4, flavor 1, and score 150.

18. Number 18 was inoculated with green mold LXXIX. A mixed infection resulted. The reaction was 12% N/100 acid. The sirup contained 91.65% sucrose and 3.12% invert sugar. The color was 10, flavor 2, and score 725; depreciation from control, color 4, flavor 1, and score 150.

19. Number 19 was inoculated with a composite culture consisting of fluorescent bacteria, yeasts and molds. The reaction was 5% N/100 acid. The sirup contained 93.28% sucrose and 4.09% invert sugar. The color was 9, flavor 3, and score 675; depreciation from control, color 3, flavor 2, and score 200.

20. Number 20 was held without inoculation at low temperature during the incubation period and reserved as a control. The reaction was 2% N/100 acid. The sirup contained 95.37%

sucrose and 1.58% invert sugar. The color was 6, flavor 1, and score 875.

SIRUPS FROM LAST RUN SAP IN 1909

No more inoculation work was conducted during the season of 1909, but several samples of sirup were made with a view of determining the possible influence of physiological changes in the tree upon the quality of sirup. As previously stated, trees were selected for this purpose which were "running sour," that is to say trees from which clear sap was no longer being obtained. The spouts usually "dry up" or cease to run quite promptly after the appearance of this phenomenon. The aim was to wait till the last day a tree was likely to run before making the experiment. A fresh tap from which the sap flowed clear was then made about 4 inches to one side of the old one. The two types of sap thus secured from the same tree at the same time would presumably be very similar in character until they left the vascular tissues. That from the old taphole, however, becomes very heavily infected as it flows from the spout while the other is relatively free from infection. Any difference in quality of the two sirups obtained under such circumstances would seem to be attributable to the influence of micro-organisms, while any differences in quality between controls of the first runs, and the last run material from the fresh taps, would reasonably be ascribed to physiological changes which had taken place within the tree.

21. Number 21 was made from sweet sap obtained by re-tapping the first sour tree observed during the season. This was drawn on April 12. The sirup contained 95.19% sucrose and 0.82% invert sugar. The color was 3, flavor 1, and score 950. The color was 3 grades superior to the first run control of the season, the flavor equal, and the total score 75 points higher.

22. Number 22 was made from sour sap obtained from the same tree at the same time as the sap for 21. The sap was

only slightly cloudy and had all run the day it was concentrated. The sirup contained 95.27% sucrose and 2.76% invert sugar. The color was 8, flavor 3, and score 700; depreciation from control (number 21), color 5, flavor 2, and score 250. Depreciation from first run control, color 2, flavor 2, and score 175.

23. Number 23 was made from sour sap obtained April 12 and held 24 hours. The sirup contained 92.56% sucrose and 3.55% invert sugar. The color was 14, flavor 3, and score 550; depreciation from control (number 24), color 7, flavor 2, and score 300. Depreciation from first run control, color 8, flavor 2, and score 325.

24. Number 24 was made from sap obtained at the same time and from the same tree as that for number 23. It was drawn from a fresh tap, but was held for twenty-four hours before concentration. The sirup contained 96.02% sucrose and 0.61% invert sugar. The color was 7, flavor 1, and score 850. Depreciation from first run control, color 1, flavor 0, and score 25.

25. Number 25 was made from sour sap which flowed April 16. The sirup contained 94.05% sucrose and 3.13% invert sugar. The color was 14, flavor 3, and score 550; depreciation from control (number 26), color 9, flavor 2, and score 350. Depreciation from first run control, color 8, flavor 2, and score 325.

26. Number 26 was obtained from the same tree as number 25 and at the same time, but from a fresh tap-hole. The samples were concentrated the same day they flowed. The sirup contained 96.42% sucrose and 0.51% invert sugar. The color was 5, flavor 1, and score 900. The color was one grade superior to the first run control, the flavor equal, and the total score 25 points higher.

The results of this single season's experiments taken alone would seem to indicate that the color and flavor of sirup are not impaired by physiological changes in the tree occurring during the sugar season. It is important to note, however, that

the season of 1909 was peculiar. There were no warm periods of importance and the interval between the first run and the last was only three weeks. The commercial season was even shorter since the experimental trees were tapped before the real season opened and most sugar makers in the vicinity gathered their buckets before April 16.

INOCULATION EXPERIMENTS IN 1910

The experience gained in 1909 emphasized the importance of more carefully controlled inoculation experiments. To facilitate the progress of the studies it seemed best to establish a laboratory where the more simple bacteriological technique could be carried out in close proximity with the woods. Accordingly, before the opening of the sugar season in 1910, a small rough wooden building was put up in the sugar woods for this purpose. (See Plate II). The floor space available was about 6 by 24 ft. The equipment consisted of an old fashioned box-stove, the top of which could be easily removed to be replaced by the evaporating pan, a blue-flame oil stove with an oven, an Arnold steam sterilizer, a microscope, Petri dishes, test tubes and other glassware, a few chemicals and the necessary sugar tools. (See Plate III). Since the laboratory was of rough construction and consequently became cold quickly, it was necessary to provide some apparatus in which the inoculated sap could be stored, in order to maintain a reasonably constant temperature during the period of incubation. For this purpose a rather crude modification of the modern fireless cooker was provided. (See Plates III and IV). This consisted of a box the approximate interior dimensions of which were, height 20 inches, width 40 inches, and length 16 feet. The walls were made of 2 double layers of matched sheathing between which was an air space of 1 inch. Building paper was used between each of the double layers of sheathing and on each side of the one inch air space. The top, bottom, and sides were of similar construction, the cover being so arranged as to break joints as

is customary with the doors of safes or refrigerators. The cover was formed in sections so as to permit opening one end without admitting cold air to the entire contents.

It was the first intention to maintain the temperature by introducing hot freestones into the incubator when the temperature of the sap began to fall. It soon appeared, however, during the extremely cold weather encountered shortly after starting the first series of the year, that this means of control was inadequate and the more satisfactory method of introducing buckets of boiling water was resorted to. This raised the air temperature in the incubator very promptly and the heat was gradually imparted to the sap. The temperature of the samples was occasionally tested by introducing a sterile thermometer into the buckets, and whenever necessary additional heat was supplied.

A self recording thermometer was placed in the incubator from the tracings of which the temperature curves here reproduced were obtained. It should be borne in mind, however, that these curves by no means represent the temperature of the sap which was far more constant than that of the air. It never fell as low nor did it rise as high. The graphs are of value, however, in that they give some indication of the conditions of incubation.

The material was incubated in new tin buckets which were thoroughly scalded immediately before filling. They had a capacity of 20 quarts and were provided with covers. Inoculation was made with a 70 cc. young culture of the specific organism employed. The controls were treated with an equivalent amount of the sterile medium which consisted of 65 cc. of sap and 5 cc. of nutrient bouillon.

Before being made into sirup each sap was thoroughly mixed and a small sample was withdrawn and sterilized to be preserved for the purposes of another investigation, the results of which it is expected will eventually be published by the station chemist. As a rule the reaction was determined by titrating against

phenolphthalein in the cold with N/100 sodium hydroxid, and a bacteriological analysis was made in order to determine the degree of success which had been attained in inoculation. The sap was then placed in a thoroughly clean pan over a brisk, flaming wood fire and evaporated to a volume of about 1 quart, when it was transferred to a white agate ware basin and concentrated to a density of 11 pounds to the gallon as indicated by the thermometer. It was the custom to determine daily the temperature at which water boiled in the laboratory, and to subtract from 219 the difference between 212 and the boiling point found, in order to arrive at the temperature at which evaporation should be discontinued during that day. Provision was thus made for fluctuations in the boiling point due to atmospheric conditions.

The sugar season of 1910 opened unusually early, before the laboratory was quite ready for use. The first run occurred on March 3 and 4, but the experimental trees were not tapped until March 6.

SERIES 4: SIRUPS 27 TO 40

The sap for this series was collected March 7, and placed in the incubating buckets in 16 quart portions. It was not so thoroughly mixed as to insure absolutely uniform chemical composition, but was handled in a manner to secure approximate uniformity. The temperature of all except two of the samples was raised to 40° C. before placing them in the incubator. One of these was allowed to stand outside where a temperature of 0° to 10° C. prevailed, while the other was heated to 80° C. and placed in the incubator. These two samples, together with one of those heated at 40° C., constituted the controls. When the temperature of the sap had dropped to 28° C. the samples were inoculated with their respective organisms and incubated for 3 days. Evaporation of the samples began at 9 a. m., March 11, under conditions which made it possible to average the production of a sirup in an hour and a quarter. The temperature of incubator may be seen by reference to figure 5.

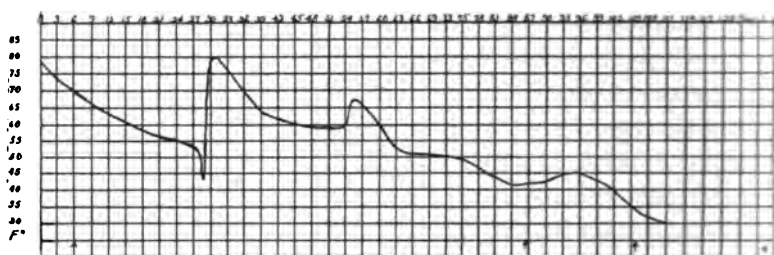


Fig. 5. Graph of incubation temperatures for series 4 ; saps 27 to 40 inclusive. The arrow heads on next to the bottom line from left to right indicate respectively the time of inoculation, the time of evaporation of the first sample and the time of evaporation of the last sample.

27. Number 27 was the control kept outside the incubator at a temperature only slightly above its freezing point. Notwithstanding the low temperature it contained 10,000 organisms per cc. although there was no evidence of clouding at the time of evaporation. The sirup contained 96.19% sucrose and 0.30% invert sugar. The color was 4, flavor 2, and score 875.

28. Number 28 was inoculated with gray yeast 24. The sap became cloudy, at first greenish, then milky. The organism was recovered in mixed culture. The plates showed 437,000 colonies per cc. The sirup contained 82.83% sucrose and 12.15% invert sugar. The color was 11, flavor 4, and score 500; depreciation from control, color 7, flavor 2, and score 375.

29. Number 29 was inoculated with fluorescent organism CXXXIX. A green type of souring developed, the sap becoming cloudy within twelve hours. The organism was recovered in practically pure culture, the plates showing 12,330,000 per cc. The sirup contained 94.19% sucrose and 0.38% invert sugar. The color was 8, flavor 2¹, and score 750; depreciation from control, color 4, flavor 0¹, and score 125.

30. Number 30 was inoculated with fluorescent organism CLIX. It was recovered apparently in pure culture from the green sour sap which resulted. The plates showed 3,262,000 colonies per cc. The sirup contained 93.75% sucrose and 0.89% invert sugar. The color was 8, flavor 2, and score 775; depreciation from control, color 4, flavor 0, and score 100.

31. Number 31 was inoculated with gray yeast CXXI. The organism was not recovered, but the plates showed a count of 5,667,000 colonies per cc., in which those of the fluorescent group greatly predominated. The sirup contained 96.62% sucrose and 0.30% invert sugar. The color was 6, flavor 2 and score 825; depreciation from control, color 2, flavor 0, and score 50.

32. Number 32 was inoculated with gray yeast CLXXX. The organism was not recovered. The plates showed a count of 5,600,000 colonies per cc., most of which were of the green fluorescent type. The sirup contained 95.91% sucrose and 0.46% invert sugar. The color was 6, flavor 2, and score 825; depreciation from control, color 2, flavor 0, and score 50.

33. Number 33 was inoculated with gray yeast CLXVIII. The organism was not recovered. The plates showed 1,950,000 colonies per cc., most of them characteristic of the fluorescent organisms. The sirup contained 95.61% sucrose and 0.23% invert sugar. The color was 7, flavor 2, and score 800, depreciation from control, color 3, flavor 0, and score 75.

34. Number 34 was the control previously mentioned as having been heated to 40° C., and placed in the incubator. As would be expected the sap promptly clouded, developing a green type of souring. The plates showed a count of 7,312,000 organisms per cc. Fluorescence was pronounced. The sirup contained 95.86% sucrose and 0.42% invert sugar. The color was 6, flavor 2¹, and score 800; depreciation from cold control, color 2, flavor 0¹, and score 75.

35. Number 35 was inoculated with red yeast CXI. Deep clouding developed and the organism was recovered in association with large numbers of fluorescent bacteria. The plates showed a count of 2,255,000 organisms per cc. The sirup contained 95.13% sucrose and 1.15% invert sugar. The color was 12, flavor 2¹, and score 650; depreciation from control, color 8, flavor 0¹, and score 225.

36. Number 36 was inoculated with red yeast CII. The sap clouded promptly but only a very few colonies of the organism were recovered. The plates showed a count of 7,312,000 in which the fluorescent group predominated. The sirup contained 96.16% sucrose and 0.61% invert sugar. The color was 9, flavor 2¹, and score 725; depreciation from control, color 5, flavor 0¹, and score 150.

37. Number 37 was inoculated with red yeast CLXXV. The organism was not recovered. The plates gave a count of 8,825,000 per cc. with pronounced fluorescence. The sirup contained 95.88% sucrose and 0.64% invert sugar. The color was 11, flavor 2¹, and score 675; depreciation from control, color 7, flavor 0¹, and score 200.

38. Number 38 was the control placed in the incubator after heating to 80° C. The plates showed a count of 162,500 colonies per cc. of which very few developed fluorescence. The sirup contained 94.80% sucrose and 0.48% invert sugar. The color was 5, flavor 2¹, and score 825; depreciation from cold control, color 1, flavor 0¹, and score 50.

39. Number 39 was inoculated with gray yeast C. Green souring developed and the organism was not recovered. The plates showed a count of 9,750,000 colonies per cc. with pronounced fluorescence. The sirup contained 96.18% sucrose and 0.26% invert sugar. The color was 7, flavor 2, and score 800; depreciation from control, color 3, flavor 0, and score 75.

40. Number 40 was a control placed in the incubator without heating. Plates showed a count of 5,850,000 organisms with the fluorescent group in predominance. The sirup contained 95.05% sucrose and 0.64% invert sugar. The color was 9, flavor 2, and score 750; depreciation from cold control, color 5, flavor 0, and score 125.

The results of this series confirmed the suspicion entertained from the inoculation trials of the previous season's work, that the yeasts did not develop readily in maple sap, but that the bacteria normally present gained the ascendancy. The changes in

the sirups of this series, with the exception of number 28, seemed to have been very largely produced by the fluorescent group of organisms. Even the cold control was apparently considerably injured both in color and flavor by the organisms developing in it during the incubation period, so that the depreciation in quality due to their action is probably greater than is indicated by the figures given above.

That this supposition is well grounded is shown by the results obtained in later series.

SERIES 5: SIRUPS 41 TO 48

Following the run obtained on March 7, there was a freeze and no considerable amount of sap was obtained again until March 14. The sap was gathered with a team and a sufficient quantity for 8 samples was withdrawn as soon as it reached the sugar house. Six of these were heated to boiling and placed in the incubating buckets while two were left unheated, their temperature being very near 0° C. On the morning of March 15, five of the heated samples were inoculated and allowed to incubate for 3 days at temperatures indicated in the graph (figure

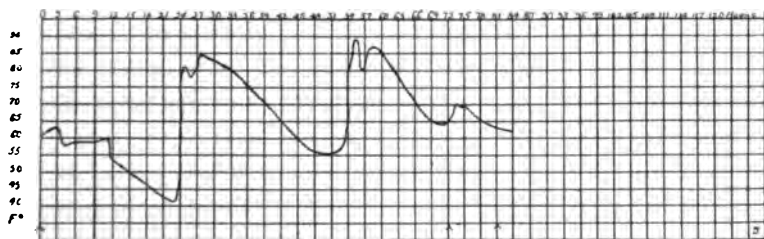


Fig. 6. Graph of incubation temperatures for series 5; saps 41 to 48 inclusive. The arrow heads on next to the bottom line from left to right indicate respectively the time of inoculation, the time of evaporation of the first sample and the time of evaporation of the last sample.

6). Before evaporation the samples were titrated, plated, and sampled as described for the previous series.

41 Number 41 was a control left standing over night before being made into sirup on the morning of March 15 when it contained 66 organisms per cc. and reacted 1% N/100 acid.

The sirup contained 97.82% sucrose and 0.45% invert sugar. The color was 4, flavor 1, and score 925.

42. Number 42 was inoculated with red yeast CVII. A milky appearance developed and the organism was recovered in considerable quantity in association with bacteria producing non-fluorescent colonies. The plates gave a count of 13,650,000 colonies per cc. The reaction was 19% N/100 acid. The sirup contained 93.27% sucrose, and 2.14% invert sugar. The color was 5, flavor 2³, and score 800; depreciation from control, color 1, flavor 1², and score 125.

43. Number 43 was a control heated to boiling and incubated for 3 days. The material became cloudy the third day and the plates showed a development of 1,625,000 organisms per cc., mostly of the non-fluorescent type. The reaction was 6.5% N/100 acid. The sirup contained 94.19% sucrose and 2.64% invert sugar. The color was 7, flavor 2, and score 800; depreciation from cold control, color 3, flavor 1, and score 125.

44. Number 44 was inoculated with fluorescent organism CXLVIII. A greenish type of clouding developed and the organism was recovered in numbers amounting to 9,000,000 per cc. The reaction was 10% N/100 acid. The sirup contained 93.03% sucrose and 1.40% invert sugar. The color was 9, flavor 3, and score 675; depreciation from control, color 5, flavor 2, and score 250.

45. Number 45 was a control incubated for 3 days in the cold. The sap remained perfectly clear. The plates revealed a bacterial content of 195,000 per cc. The reaction was 4.5% N/100 acid. The sirup contained 96.28% sucrose and 0.51% invert sugar. The color was 4, flavor 1, and score 925; depreciation from control (number 41), color 0, flavor 0, and score 0.

46. Number 46 was inoculated with pink coccus CIV. Pronounced clouding of the milky type and a yeasty odor developed. The plates showed a count of 14,300,000 organisms per cc. among which the introduced organism was predominant. The reaction was 10% N/100 acid. The sirup contained

95.07% sucrose and 1.05% invert sugar. The color was 6, flavor 2, and score 825; depreciation from control, color 2, flavor 1, and score 100.

47. Number 47 was inoculated with pink coccus IV. A milky type of souring developed. The plates showed a count of 1,950,000 organisms per cc., the majority of which apparently were produced by the introduced organism. The reaction was 9.6% N/100 acid. The sirup contained 88.81% sucrose and 7.90% invert sugar. The color was 6, flavor 3, and score 750; depreciation from control, color 2, flavor 2, and score 175.

48. Number 48 was inoculated with gray yeast CLXXX. The sap became milky and developed a yeasty odor. The organism was recovered in association with bacteria the colonies of which resembled those of the subtilis group. The plates gave a total count of 1,625,000 per cc. The reaction was 16.7% N/100 acid. The sirup contained 93.89% sucrose and 2.35% invert sugar. The color was 6, flavor 2², and score 775; depreciation from control, color 2, flavor 1², and score 150.

SERIES 6: SIRUPS 49 TO 57

Series 6 was made from sap which flowed on March 20. A sufficient quantity was gathered at four o'clock for 9 samples and the material was thoroughly mixed to insure uniformity of chemical composition. Two of the samples were left untreated while the others were heated to boiling, cooled, and, with the exception of one, inoculated. The air temperature maintained during the 3 days' incubation is shown in the accompanying graph (figure 7).

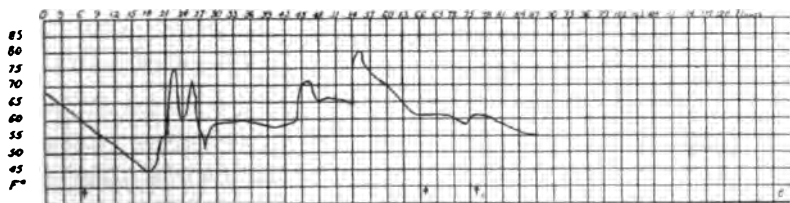


Fig. 7. Graph of incubation temperatures for series 6; saps 49 to 57 inclusive. The arrow heads on next to the bottom line from left to right indicate respectively the time of inoculation, the time of evaporation of the first sample and the time of evaporation of the last sample.

49. Number 49 was a control evaporated immediately after gathering. A bacteriological analysis showed a count of only 100 organisms per cc. The reaction was 1% N/100 acid. The sirup contained 96.51% sucrose and 0.42% invert sugar. The color was 2, flavor 1, and score 975. This sirup was considered the best specimen obtained during the entire period covered by the work.

50. Number 50 was inoculated with pink coccus XLIX. Deep clouding resulted and the coccus was recovered in practically pure culture. The plates showed a count of 1,950,000 organisms per cc. The reaction was 8% N/100 acid. The sirup contained 93.83% sucrose and 2.20% invert sugar. The color was 6, flavor 2¹, and score 800; depreciation from control, color 4, flavor 1¹ and score 175.

51. Number 51 was inoculated with pink coccus CVI. The sap became deeply clouded. The organism was recovered, the plates showing a count of 4,225,000 per cc. with the introduced species in predominance. The reaction was 3.5% N/100 acid. The sirup contained 97.30% sucrose and 0.65% invert sugar. The color was 4, flavor 2, and score 875; depreciation from control, color 2, flavor 1, and score 100.

52. Number 52 was inoculated with gray yeast CLXII. A milky white clouding developed. The organism was recovered in mixed culture. The plates showed a count of 1,275,000 colonies per cc. About 30,000 of these were characteristic of the introduced organism, while most of the others were bacterial colonies characteristic of the subtilis group. The sirup contained 96.84% sucrose and 1.21% invert sugar. The color was 5, flavor 2, and score 850; depreciation from control, color 3, flavor 1, and score 125.

53. Number 53 was inoculated with gray yeast CLXXI. A milky type of souring developed. The organism was recovered in association with bacteria of the subtilis and fluorescent groups. The plates showed a count of 630,000 organisms per cc. The reaction was 6% N/100 acid. The sirup contained 92.13%

sucrose and 3.96% invert sugar. The color was 6, flavor 3, and score 750; depreciation from control, color 4, flavor 2, and score 225.

54. Number 54 was inoculated with pink yeast CXXVI. A deep milky appearance developed to a pronounced degree and an unpleasant yeasty odor was noted. The organism was recovered, the plates showing a count of 1,300,000 organisms per cc. The reaction was 8.5% N/100 acid. The sirup contained 94.11% sucrose, and 2.71% invert sugar. The color was 7, flavor 2², and score 750; depreciation from control, color 5, flavor 1², and score 225.

55. Number 55 was inoculated with a non-fluorescent organism CVIII. A milky type of souring developed in which a brownish color was evident in strong light, and a peculiar bacterial odor was noted. The organism was recovered in practically pure culture. The plates showed a total count of 7,230,000 organisms per cc. The reaction was 6% N/100 acid. The sirup contained 94.76% sucrose and 2.38% invert sugar. The color was 5, flavor 2, and score 850; depreciation from control, color 3, flavor 1, and score 125.

56. Number 56 was the incubator control heated to boiling and placed in the incubator with the other samples without inoculation. It clouded slightly during the incubation period. The plates poured revealed a bacterial count of 320,000 per cc. The reaction was 3.1% N/100 acid. The sirup contained 96.02% sucrose and 1.35% invert sugar. The color was 5, flavor 2, and score 850; depreciation from control, color 3, flavor 1, and score 125.

57. Number 57 was the control not heated and retained outside the incubator at low temperature during the incubation period. At the time of evaporation it had a temperature of 10° C. The plates showed a development of 37,000 bacteria per cc. The reaction was 2.5% N/100 acid. The sirup contained 96.47% sucrose and 0.60% invert sugar. The color was 2, flavor 1, and score 975; depreciation from control (number

49), color 0, flavor 0, and score 0. While this sample was given the same score as number 49, it was considered by the expert who scored the samples to be very slightly its inferior.

SERIES 7: SIRUPS 58 TO 65

The sap for this series ran on March 21. It was collected with the general supply in a gathering tub late in the evening, strained into buckets and allowed to remain over night in a cold place. On the morning of the following day all but one of the samples was heated to boiling and cooled at once by placing the buckets in ice water. As soon as cool the material was placed in the incubator and cultures of organisms were added to the samples designed for inoculation. The air temperature maintained during the incubation period appears on the accompanying graph (figure 8).

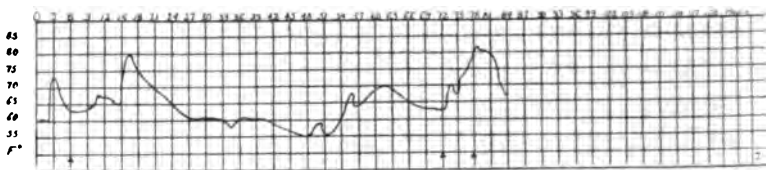


Fig. 8. Graph of incubation temperatures for series 7 ; saps 58 to 65 inclusive. The arrow heads on next to the bottom line from left to right indicate respectively the time of inoculation, the time of evaporation of the first sample and the time of evaporation of the last sample.

58. Number 58 was a control evaporated on the morning of March 22. The plates developed 380 colonies per cc., among which those of the fluorescent bacteria predominated. The reaction was 3% N/100 acid. The sirup contained 97.01% sucrose and 0.43% invert sugar. The color was 3, flavor 1, and score 950. This sample was regarded by the judge as the third best sirup obtained during the entire series of experiments.

59. Number 59 was inoculated with red yeast CXXIII. A brownish-white clouding resulted. The organism was recovered in association with spore-bearing bacteria apparently belonging to the subtilis group. The plates showed a development of 325,000 colonies per cc. The reaction was 8% N/100 acid. The sirup contained 94.74% sucrose and 2.03% invert sugar. The color

was 7, flavor 3, and score 725; depreciation from control, color 4, flavor 2, and score 225.

60. Number 60 was inoculated with red yeast CXIII. A milky brown souring developed. The organism was recovered in association with bacteria belonging to the fluorescent and subtilis groups. The count showed 1,950,000 colonies per cc. The reaction was 8.4% N/100 acid. The sirup contained 95.44% sucrose and 1.76% invert sugar. The color was 6, flavor 3, and score 750; depreciation from control, color 3, flavor 2, and score 200.

61. Number 61 was inoculated with red yeast CX. A reddish-brown clouding developed. The organism was recovered, the plates showing a count of 650,000 colonies per cc. among which those of the introduced organism predominated. The reaction was 5.5% N/100 acid. The sirup contained 95.80% sucrose and 1.77% invert sugar. The color was 9, flavor 3, and score 675; depreciation from control, color 6, flavor 2, and score 275.

62. Number 62 was inoculated with red yeast 25. A reddish clouding developed accompanied by a sour yeasty odor. The organism was recovered in association with bacteria, 650,000 colonies per cc. being developed of which practically one-third were those of the introduced organism. The reaction was 9.5% N/100 acid. The sirup contained 89.27% sucrose and 7.30% invert sugar. The color was 9, flavor 4, and score 550; depreciation from control, color 6, flavor 3, and score 400.

63. Number 63 was inoculated with red yeast CXIV. The sap became cloudy with a reddish-brown hue. Out of the 975,000 colonies per cc. which developed on the plates, 175,000 were characteristic of the introduced organism. The reaction was 11% N/100 acid. The sirup contained 89.06% sucrose and 7.63% invert sugar. The color was 8, flavor 3, and score 700; depreciation from control, color 5, flavor 2, and score 250.

64. Number 64 was inoculated with red yeast CXX. A sour yeasty odor developed and the sap became deeply clouded with a reddish cast. The organism was recovered. The plates

showed a development of 97,500 colonies per cc., most of which were characteristic of the introduced organism. The reaction was 10% N/100 acid. The sirup contained 91.64% sucrose and 5.86% invert sugar. The color was 8, flavor 3, and score 700; depreciation from control; color 5, flavor 2, and score 250.

65. Number 65 was a control retained in the incubator. The sap clouded early and appeared like the inoculated samples. The plates showed a development of 1,950,000 colonies of various species. The reaction was 9% N/100 acid. The sirup contained 91.89% sucrose and 3.52% invert sugar. The color was 6, flavor 4, and score 625; depreciation from control (number 58), color 3, flavor 3, and score 325.

INFLUENCE OF THE CONTAINER UPON THE QUALITY OF THE SIRUP

Under the above heading will be discussed the sirups made from the saps previously referred to in connection with the discussion of the influence of the container upon the bacterial content of the sap (page 343). It will be remembered that six trees were employed which had been tapped with special care and upon which tin buckets were hung. For the purpose of a part of this experiment, they were replaced by wooden ones. The tin buckets were kept free from the accumulation of micro-organisms by frequent washings and scaldings.

66. Number 66 was made from sap collected March 21 and 22, in clean tin buckets. The composite sample from the 6 trees contained 140 organisms per cc., most of them of a single type previously mentioned as characteristic of tree 3 (Plate VI). The reaction was 2% N/100 acid. The sirup contained 96.62% sucrose and 0.41% invert sugar. The color was 3, flavor 1, and score 950.

67. Number 67 was made from sap obtained from the same trees as was number 66 but it flowed two days later on March 23 and 24. The tin buckets were replaced by wooden buckets formerly employed in the sugar place where the work was done. They had been soaked out in the usual way and thoroughly

washed before being hung on the trees. That the crevices and interstices of the wood afforded ample lodging places for micro-organisms is readily seen from the fact that 6,500,000 colonies per cc. developed from the mixture of sap obtained, and only a few of them were characteristic of the organism from tree 3 (Plate VII). The reaction was 5.5% N/100 acid. The sirup contained 88.25% sucrose and 6.21% invert sugar. The color was 9, flavor 4, and score 550; depreciation from control (number 66), color 6, flavor 3, and score 400.

SERIES 8: SIRUPS 68 TO 73

The sap of this series ran on March 22, and was collected in the evening and stored over night in buckets, at a temperature slightly above its freezing point. The following morning the samples were thoroughly mixed, and all but one were heated to boiling and allowed to cool in water. At 3 p. m., they were placed in the incubator and inoculated. The temperature maintained during the three days' incubation period may be seen by reference to the graph (figure 9).

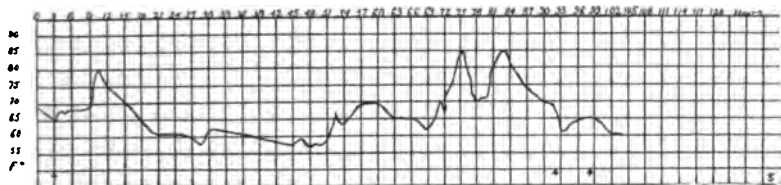


Fig. 9. Graph of incubation temperatures for series 8 ; saps 68 to 73 inclusive. The arrow heads on next to the bottom line from left to right indicate respectively the time of inoculation, the time of evaporation of the first sample and the time of evaporation of the last sample.

68. Number 68 was a control boiled down on the morning of March 23. Just before evaporation it contained 500 organisms per cc. The reaction was 2.5% N/100 acid. The sirup contained 96.90% sucrose and 0.51% invert sugar. The color was 4, flavor 1, and score 925.

69. Number 69 was inoculated with fluorescent organism CLIV. It was recovered in practically pure culture from the green sour sap which resulted. The plates showed a count of

19,500,000 organisms per cc. The reaction was 10% N/100 acid. The sirup contained 93.87% sucrose and 1.59% invert sugar. The color was 9, flavor 3, and score 675; depreciation from control, color 5, flavor 2, and score 250.

70. Number 70 was inoculated with green fluorescent organism CXXXIII. A greenish-brown souring developed promptly and the organism was recovered in practically pure culture. The plates showed a count of 20,400,000 per cc. The reaction was 10% N/100 acid. The sirup contained 93.47% sucrose and 2.46% invert sugar. The color was 11, flavor 4, and score 500; depreciation from control, color 7, flavor 3, and score 425.

71. Number 71 was inoculated with green fluorescent organism CXLVII. A greenish-white clouding appeared within a day. The plates showed a development of 23,400,000 organisms per cc., practically all of which were of a type characteristic of the introduced species. The reaction was 6.5% N/100 acid. The sirup contained 93.69% sucrose and 0.58% invert sugar. The color was 14, flavor 4, and score 425; depreciation from control, color 10, flavor 3, and score 500.

72. Number 72 was inoculated with green fluorescent organism CLII. A green souring occurred. The plates showed a development of 29,250,000 colonies per cc., practically all of the fluorescent type. The reaction was 10% N/100 acid. The sirup contained 95.07% sucrose and 0.87% invert sugar. The color was 13, flavor 4, and score 450. Depreciation from control, color 9, flavor 3, score 475.

73. Number 73 was inoculated with green fluorescent organism CLVIII. The sap promptly clouded, becoming at first greenish and then milky. The plates showed a development of 23,400,000 colonies per cc. with pronounced green fluorescence. The reaction was 2.3% N/100 acid. The sirup contained 97.47% sucrose, and 0.68% invert sugar. The color was 6, flavor 2, and score 825; depreciation from control, color 2, flavor 1, and score 100.

SERIES 9: SIRUPS 74 TO 81

The sap for this series was gathered in pails and brought to the laboratory about 10 p. m., March 24. It was carefully mixed and divided into 18-quart portions, all but one of which were heated to boiling. The following morning the samples which had been heated were placed in the incubator and inoculated, with the exception of one which was reserved as an incubator control. The air temperature maintained during the incubation period may be seen by referring to the accompanying graph (figure 10).

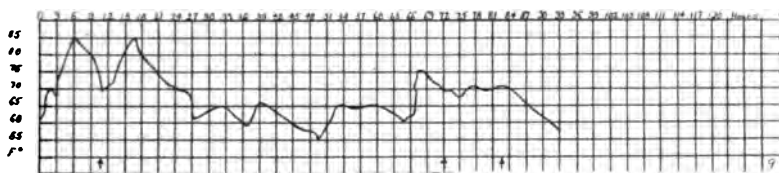


Fig. 10. Graph of incubation temperatures for series 9 ; saps 74 to 81 inclusive. The arrow heads on next to the bottom line from left to right indicate respectively the time of inoculation, the time of evaporation of the first sample and the time of evaporation of the last sample.

74. Number 74 was the control which was not heated. It was evaporated on the morning of March 25. The sap contained 750 organisms per cc. The reaction was 3% N/100 acid. Unfortunately the sirup was slightly burned in the pan so that its color and flavor were seriously impaired. For this reason the sirups of this series have been referred to number 68 as a control. Sirup 74 contained 96.36% sucrose and 0.70% invert sugar. The color was 9, flavor 4, and score 550; depreciation from control (number 68), color 5, flavor 3, and score 375.

75. Number 75 was inoculated with fluorescent organism CLXXIX. The plates showed a development of 10,400,000 colonies per cc. divided between those characteristic of the fluorescent group and those of another organism of the subtilis type. The reaction was 10% N/100 acid. The sirup contained 84.74% sucrose and 10.77% invert sugar. The color was 9, flavor 3, and score 675; depreciation from control, color 5, flavor 2, and score 250.

76. Number 76 was inoculated with fluorescent organism CLV. The organism was recovered, but in association with great number of the spore-bearing bacteria noted in connection with the previous sample. The plates showed a count of 4,875,000 organisms per cc. The reaction was 10.7% N/100 acid. The sirup contained 87.03% sucrose and 8.94% invert sugar. The color was 10, flavor 3, and score 650; depreciation from control, color 6, flavor 2, and score 275.

77. Number 77 was inoculated with green fluorescent organism CLXXVII. 11,700,000 colonies per cc. were obtained. These were divided between the two types of organisms mentioned for the preceding samples of this series. The reaction was 10.1% N/100 acid. The sirup contained 88.13% sucrose and 8.24% invert sugar. The color was 8, flavor 3, and score 700; depreciation from control, color 4, flavor 2, and score 225.

78. Number 78 was inoculated with green fluorescent organism XXXVI. Here again two types of colonies were recovered. The total count was 14,625,000 colonies per cc. The reaction was 11.2% N/100 acid. The sirup contained 83.86% sucrose and 10.84% invert sugar. The color was 8, flavor 4, and score 575; depreciation from control, color, 4, flavor 3, and score 350.

79. Number 79 was inoculated with non-fluorescent organism CLXIII which itself belongs to the subtilis group. 6,500,000 colonies per cc. were recovered, practically all of which resembled those of the introduced organism. The reaction was 25.4% N/100 acid. The sirup contained 78.78% sucrose and 15.25% invert sugar. The color was 7, flavor 4, and score 600; depreciation from control, color 3, flavor 3, and score 325.

80. Number 80 was inoculated with pink yeast CLXVIII. The organism was not recovered. 9,750,000 colonies were obtained per cc., all of which were characteristic of the subtilis type. The sirup contained 79.20% sucrose and 16.13% invert sugar.

The color was 10, flavor 4, and score 525; depreciation from control, color 6, flavor 3, and score 400.

81. Number 81 was a control heated to boiling and left in the incubator without inoculation. It developed 3,250,000 colonies per cc., typical of the subtilis group. The reaction was 10% N/100 acid. The sirup contained 89.23% sucrose and 7.51% invert sugar. The color was 7, flavor 4, and score 600; depreciation from control (number 68), color 3, flavor 3, and score 325.

It is evident that the sap used in the above series was heavily contaminated by some spore-bearing organism which apparently has the power of inverting sugar and which exercises a further detrimental influence upon the flavor of sirup. Reference to the laboratory notes shows that after being heated the samples were placed without being covered on the top of instead of within the incubator to cool over night, in order that they might be ready for inoculation the following morning; but to prevent the entrance of falling dust a shelter of new clean paper was supported a few inches above the tops of the buckets. During the night there occurred a heavy wind storm. The ground was partially bare and it is possible that spore laden dust entered the laboratory through the rather large cracks which had opened in the single layer of boards constituting the floor, and that infection was produced in this way. Unfortunately the infection was not suspected until the results of the bacteriological and chemical analyses were known. Cultures of the organism were not secured so that its identity is uncertain, but the agar plate colonies were strikingly similar both in macroscopic and microscopic appearance to those of *Bacillus subtilis* and spore formation was apparent on unstained preparations from 4 days' agar colonies.

SUGAR AND SIRUP FROM SOUR SAP

The inoculation work of the season was completed with the preceding series, but a few experiments were made with natural sour sap.

82. Number 82 was made from sap collected March 29 from two trees located in a sheltered position which received an abundance of sunlight. The sap obtained from these trees naturally soured somewhat earlier than the average sap in the orchard as a whole and was just about ready to stop running at the time this experiment was started. The sap had been allowed to remain without being collected since the first indications of serious souring, 2 or 3 days before. Neither titration nor bacteriological count was made. The sap was concentrated to sugar at once, to see whether it would grain properly, which it did. The sample was neither scored nor analyzed.

83. Number 83 was made from sap collected April 2 and represented all the sap that had flowed from the trees mentioned under 82, since March 29. At the time of collection these trees had apparently entirely ceased running. The sap contained 43,875,000 organisms per cc. The reaction was 6% N/100 acid. Like the preceding sample this was evaporated at once to a sugar which grained readily. It was neither scored nor analyzed.

84. Number 84 was made April 4 from a part of the same sap from which 83 was made. The sirup contained 91.14% sucrose and 2.83% invert sugar. The color was 20, flavor 3¹, and score 350.

85. Number 85 was made from sour sap collected April 2, but which had been accumulating in the buckets for several days. It contained 11,275,000 organisms per cc. The reaction was 6% N/100 acid. The sirup contained 94.68% sucrose and 1.57% invert sugar. The color was darker than 20, flavor 3¹, and score 325.

86. Number 86 had exactly the same history as 85 except that when nearly evaporated to sirup it was allowed to cool to about 35° C., following which the beaten white of two eggs was added in order to test the clarifying power of this treatment. The boiling was then continued. The sirup contained 93.21% sucrose and 1.23% invert sugar. The color was darker than

20 but not quite as dark as that of number 85. The flavor was 3¹, and score 325.

SIRUP FROM LAST RUN SAP IN 1910

The plan pursued in the following experiments was exactly the same as that described for similar experiments the previous year (page 357). The first trees were retapped April 3. It was the intention to continue the experiments upon different trees until the flow of sap was so reduced that it was impossible to secure enough to make even a small sample of sirup. Unfortunately for the purpose of the work the weather became warm and night freezes ceased altogether, so that only a single experiment of this character was possible.

87. Number 87 was secured from the fresh tap-hole of a tree which had yielded sour sap for a considerable number of days and upon which the leaf buds were already opened. The sap contained 5 organisms per cc. The reaction was 2.5% N/100 acid. The sirup contained 97.27% sucrose and 0.26% invert sugar. The color was 4, flavor 5, and score 525; depreciation from first run control, color 0, flavor 3, score 250.

88. Number 88 was made from the same tree as number 87 but from the sap flowing from the old tap-hole. The plates gave a count of 73,125,000 organisms per cc. The reaction was 4% N/100 acid. The sirup contained 94.56% sucrose and 1.79% invert sugar. The color was 11, flavor 6, and score 250; depreciation from control (number 87), color 7, flavor 1, and score 275. Depreciation from first run control, color 7, flavor 4, score 625.

The results afforded by these two samples are interesting and significant, for it will be observed that the flavor of the last run material in 1910 was very seriously impaired, even when bacteria were excluded, the typical buddy flavor being present in an unmistakable degree, while the color remained light. Manifestly the poor flavor of No. 87 can not be attributed to the influence of the bacteria present for they were practically absent, but 5 per cc. being found. Its cause must be sought elsewhere; and naturally

one suspects physiological changes occurring within the tree. These results do not agree with those obtained in 1909, and cited in bulletin 151, as well as on pages 357-358 in this issue; but the contradiction may probably be explained by the divergencies in the prevailing weather conditions during the two seasons. The spring of 1910 was interrupted by periods of warm weather which started the trees into vegetative activity at least two or three weeks before the close of the sugar season, whereas the season of 1909 was short and exhibited no warm periods intervening with cold spells.

The small amount of invert sugar present in No. 87 confirms the suggestion obtained from the results of 1909, that the invert sugar content of a sap tends to decrease rather than increase as the season advances.

INOCULATION EXPERIMENTS IN 1911

The considerable number of instances in which the plates from incubated samples failed to return approximately pure cultures of the introduced organism in 1910, led to a modification of the procedure for 1911. The incubation buckets were discarded and a large number of 2 quart glass preserving jars were secured in which the sap was placed and subjected to fractional sterilization before inoculation. The covers were left on the jars but were not clamped down, so that the protection from infection was approximately the same as is afforded in Petri dish cultures. For purposes of sterilization, the jars were placed in a steam chamber and treated as is customary in sterilization with flowing steam at atmospheric pressure. Except in the last series of the season the sap was subjected to two sterilizations only. The last series was steamed on each of three consecutive days. This change was made because one of the jars of the control of the preceding series developed cloudiness, which was found upon examination to be due to spore-bearing organisms of the subtilis type. As in the preceding season, the success of the inoculation experiments was controlled by bacteriological examination in

which the poured plate method was employed, but aliquots were not used and no count of the number of recovered organisms was obtained.

The saps were mixed and titrated immediately before concentration, plates were poured to determine the character of the infection, and a sample was removed and sterilized for the purpose of the experiment previously mentioned. The sirups were handled in all respects like those of the preceding year.

SERIES 10: SIRUPS 89 TO 96

The sap for this series flowed on March 22 and was gathered and given the first sterilization late in the afternoon of that day. The second sterilization followed after an interval of 24 hours. The samples were inoculated as soon as they were sufficiently cool, and were incubated for $3\frac{1}{2}$ days. The air temperature maintained in the incubator is shown in the accompanying graph (figure 11).

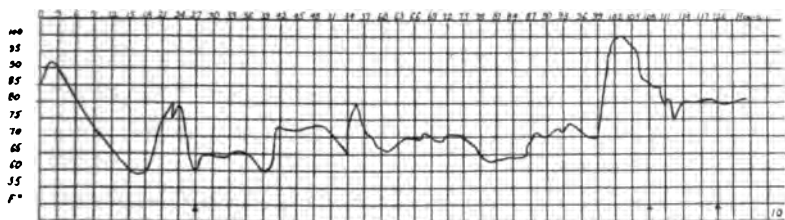


Fig. 11. Graph of incubation temperatures for series 10; saps 89 to 96 inclusive. The arrow heads on next to the bottom line from left to right indicate respectively the time of inoculation, the time of evaporation of the first sample and the time of evaporation of the last sample.

89. Number 89 was a control boiled down the day it was obtained from the trees. The reaction was 1.2% N/100 acid. The sirup contained 95.81% sucrose and 0.34% invert sugar. The color was 3, flavor 2, and score 900.

90. Number 90 was inoculated with *Bacillus accris*, a stringy sap organism, strain CCXVII. A very deep milky type of souring occurred and the material became quite stringy, though it was by no means as ropy as unsterilized sap inoculated with the same organism. An unpleasant yeasty odor was pro-

nounced. The reaction was 25.4% N/100 acid. The sirup contained 86.72% sucrose and 7.20% invert sugar. The color was 7, flavor 4, and score 600; depreciation from control, color 4, flavor 2, and score 300.

91. Number 91 was inoculated with fluorescent organism CXL. A characteristic green type of souring developed and the organism was recovered. The reaction was 1.5% N/100 acid. The sirup contained 94.76% sucrose and 0.40% invert sugar. The color was 6, flavor 3, and score 750; depreciation from control, color 3, flavor 1 and score 150.

92. Number 92 was inoculated with fluorescent organism CXII. A green type of souring developed and the organism was recovered. The reaction was 1.4% N/100 acid. The sirup contained 95.00% sucrose and 0.52% invert sugar. The color was 7, flavor 3, and score 725; depreciation from control, color 4, flavor 1, and score 175.

93. Number 93 was inoculated with green fluorescent organism LI. Typical green souring developed and the organism was recovered. The reaction was 1.2% N/100 acid. The sirup contained 95.43% sucrose and 0.43 invert sugar. The color was 6, flavor 2, and score 825; depreciation from control, color 3, flavor 0, and score 75.

94. Number 94 was inoculated with green fluorescent organism CXLI. Green souring developed and the organism was recovered. The reaction was 1.2% N/100 acid. The sirup contained 94.68% sucrose and 0.52% invert sugar. The color was 7, flavor 4, and score 600; depreciation from control, color 4, flavor 2, and score 300.

95. Number 95 was inoculated with *Bacillus aceris*, a stringy sap organism, strain LXXXVII. A milky type of souring with slight stringiness developed. The organism was recovered. The reaction was 27% N/100 acid. The sirup contained 90.85% sucrose, and 5.04% invert sugar. The color was 6, flavor 3, and score 750; depreciation from control, color 3, flavor 1, and score 150.

96. Number 96 was the control sterilized and placed in the incubator without inoculation. The plates were sterile. The reaction was 0.5% N/100 acid. The sirup contained 95.33% sucrose and 0.44% invert sugar. The color was 5, flavor 2, and score 850; depreciation from control (number 89), color 2, flavor 0, and score 50.

SERIES II: SIRUPS 97 TO 104

The sap of this series was obtained on March 26. It was sterilized at once and again on March 27, and inoculated in the evening of the latter day and incubated for 3½ days. The temperature is shown in the accompanying graph (fig. 12).

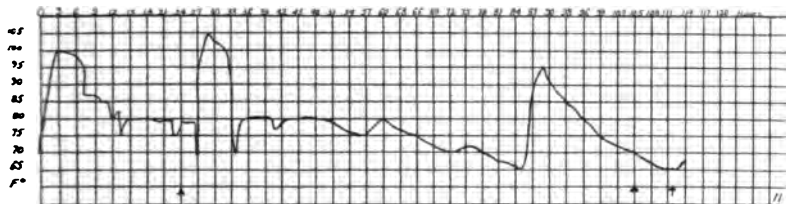


Fig. 12. Graph of incubation temperatures for series II; saps 97 to 104 inclusive. The arrow heads on next to the bottom line from left to right indicate respectively the time of inoculation, the time of evaporation of the first sample and the time of evaporation of the last sample.

97. Number 97 was a control evaporated March 26 immediately after gathering. The reaction was 0.5% N/100 acid. The sirup contained 96.04% sucrose and 0.19% invert sugar. The color was 3, flavor 1, and score 950.

98. Number 98 was inoculated with pink yeast CXXXII. A milky clouding developed accompanied by a very unpleasant odor. The organism was recovered. The reaction was 1.5% N/100 acid. The sirup contained 86.70% sucrose and 8.69% invert sugar. The color was 9, flavor 4, and score 550; depreciation from control, color 6, flavor 3, and score 400.

99. Number 99 was inoculated with red yeast CX. A red-dish brown type of souring developed, accompanied by a yeasty odor. The organism was recovered. The reaction was 1.4% N/100 acid. The sirup contained 94.82% sucrose and 2.05%

invert sugar. The color was 7, flavor 4, and score 600; depreciation from control, color 4, flavor 3, and score 350.

100. Number 100 was inoculated with fluorescent organism CXLVIII. A green type of souring developed and the organism was recovered. The reaction was 1.1% N/100 acid. The sirup contained 96.21% sucrose and 0.93% invert sugar. The color was 7, flavor 3, and score 725; depreciation from control, color 4, flavor 2, and score 225.

101. Number 101 was inoculated with fluorescent organism 5. A characteristic type of souring appeared and the organism was recovered. The reaction was 1.2% N/100 acid. The sirup contained 96.45% sucrose and 0.94% invert sugar. The color was 8, flavor 3, and score 700; depreciation from control, color 5, flavor 2, and score 250.

102. Number 102 was inoculated with green fluorescent organism XXXIII. A green type of souring developed and the organism was recovered. The reaction was 4.5% N/100 acid. The sirup contained 95.67% sucrose and 1.14% invert sugar. The color was 7, flavor 4, and score 600; depreciation from control, color 4, flavor 3, and score 350.

103. Number 103 was inoculated with green fluorescent organism XXXVI. A green type of souring developed and the organism was recovered. The reaction was 1.4% N/100 acid. The sirup contained 95.38% sucrose and 1.35% invert sugar. The color was 7, flavor 4, and score 600; depreciation from control, color 4, flavor 3, and score 350.

104. Number 104 was a control sterilized and placed in the incubator without inoculation. The plates were sterile. The reaction was 0.6% N/100 acid. The sirup contained 97.00% sucrose and 0.41% invert sugar. The color was 4, flavor 2, and score 875; depreciation from control (number 97), color 1, flavor 1, and score 75.



PLATE III.—Interior view of the field laboratory. (See page 359).



PLATE IV.—Incubator. (See pages 359-360).

SERIES 12: SIRUPS 105 TO 112

The sap for this series was collected on March 27, given two sterilizations, inoculated on the morning of March 29, and incubated for 3 days at the temperatures indicated in the accompanying graph (figure 13).

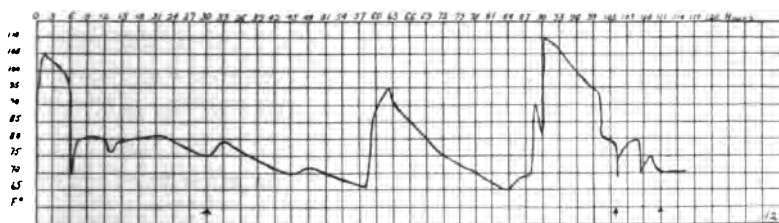


Fig. 13. Graph of incubation temperatures for series 12 ; saps 105 to 112 inclusive. The arrow heads on next to the bottom line from left to right indicate respectively the time of inoculation, the time of evaporation of the first sample and the time of evaporation of the last sample.

105. Number 105 was a control evaporated on the morning of March 28. The reaction was 1% N/100 acid. The sirup contained 96.23% sucrose and 0.24 invert sugar. The color was 3, flavor 2, and score 900.

106. Number 106 was inoculated with red yeast CCIII, which evidently made a feeble growth as the organism was not recovered from the rather high dilutions employed in plating. The reaction was 4.1% N/100 acid. The sirup contained 97.30% sucrose and 0.66% invert sugar. The color was 7, flavor 3, and score 725 ; depreciation from control, color 4, flavor 1, and score 175.

107. Number 107 was inoculated with pink coccus CVI. A pale milky type of souring developed. The organism was recovered. The reaction was 4% N/100 acid. The sirup contained 94.52% sucrose and 0.69% invert sugar. The color was 5, flavor 4, and score 650 ; depreciation from control, color 2, flavor 2, and score 250.

108. Number 108 was inoculated with pink yeast CLXXVIII, but only one colony was recovered. The reaction was 3.3% N/100 acid. The sirup contained 95.37% sucrose and

0.90% invert sugar. The color was 4, flavor 3, and score 800; depreciation from control, color 1, flavor 1, and score 100.

109. Number 109 was inoculated with gray yeast 24. The organism made a remarkable growth as evidenced by the deep clouding of the material and a flaky sediment, as well as by the semi-mycelial growth suspended in the sap. A distinctly yeasty odor developed which became very offensive when the material was heated for evaporation. The specific organism was recovered in great numbers. The reaction was 41% N/100 acid. The sirup contained 67.33% sucrose and 28.25% invert sugar. The color was 10, flavor 4, and score 525; depreciation from control, color 7, flavor 2, and score 375.

110. Number 110 was inoculated with gray yeast CXXI. The organism was recovered from the material which developed a dull brownish white appearance with clouding. The reaction was 3.3% N/100 acid. The sirup contained 97.09% sucrose and 1.74% invert sugar. The color was 6, flavor 4, and score 625; depreciation from control, color 3, flavor 2, and score 275.

111. Number 111 was inoculated with green mold CCCI belonging to the *Eurotium* genus. The organism made moderate growth as could be seen by the tufts of mycelium developing in the material and also from the plates. The reaction was 2% N/100 acid. The sirup contained 93.31% sucrose and 4.39% invert sugar. The color was 7, flavor 4, and score 600; depreciation from control, flavor 4, color 2, and score 300.

112. Number 112 was the control sterilized and held in the incubator without inoculation. The reaction was 1% N/100 acid. The sirup contained 97.60% sucrose and 1.11% invert sugar. The color was 5, flavor 2, and score 850; depreciation from control (number 105), color 2, flavor 0, and score 50.

SERIES 13; SIRUPS 113 TO 120

The sap for this series flowed on March 30, and was stored outdoors over night at a temperature below freezing, as shown by the ice which formed in the cans during the night. The

113. Number 113 was a control evaporated on the morning of March 31. The reaction was 2% N/100 acid. The sirup contained 96.97% sucrose and 0.61% invert sugar. The color was 4, flavor 2, and score 875.

115. Number 115 was inoculated with gray yeast CXXI. A milky type of souring developed. The organism was recovered. The reaction was 4.7% N/100 acid. The sirup contained 95.14% sucrose and 1.52% invert sugar. The color was 7, flavor 4, and score 600; depreciation from control, color 3, flavor 2, and score 275.

116. Number 116 was a composite inoculated with red yeast LXII and fluorescent pseudomonas CXLV. A green type of souring developed. The fluorescent organisms appeared in large numbers on the plates, but the yeast was not recovered.

The reaction was 3.7% N/100 acid. The sirup contained 95.62% sucrose and 0.68% invert sugar. The color was 8, flavor 4, and score 575; depreciation from control, color 4, flavor 2, and score 300.

117. Number 117 was inoculated with green mold CCCI belonging to the *Eurotium* genus. An excellent growth occurred. Some of the tufts of mycelium rose to the top and developed characteristic green spores. The reaction was 7.4% N/100 acid. The sirup contained 91.09% sucrose and 3.72% invert sugar. The color was 9, flavor 4, and score 550; depreciation from control, color 5, flavor 2, and score 325.

118. Number 118 was a composite inoculated with gray yeast CXXI and fluorescent *pseudomonas* CXLV. The bacteria were recovered in great numbers in association with a few yeast colonies. The type of souring was characteristic of the fluorescent organism, but there was also evidence of the odor which is associated with the development of yeast. The reaction was 4.8% N/100 acid. The sirup contained 95.69% sucrose and 0.98% invert sugar. The color was 7, flavor 4, and score 600; depreciation from control, color 3, flavor 2, and score 275.

119. Number 119 was a composite inoculated with *Eurotium* CCCI and fluorescent *pseudomonas* CXLV. The mold apparently made only very slight growth, while the bacteria developed luxuriantly. The reaction was 4.2% N/100 acid. The sirup contained 96.27% sucrose and 0.81% invert sugar. The color was 7, flavor 2, and score 800; depreciation from control, color 3, flavor 0, and score 75.

120. Number 120 was an incubator control, sterilized and held without inoculation. The reaction was 4.6% N/100 acid. The sirup contained 95.02% sucrose and 0.57% invert sugar. The color was 5, flavor 3, and score 775; depreciation from control (number 113), color 1, flavor 1, and score 100.

SIRUPS FROM LAST RUN SAP IN 1911

As in two preceding years, as soon as the season was sufficiently advanced, trees which were running a sour sap were selected to be retapped in order to procure material from both fresh and sour tap-holes of the same tree at the same time.

121. Number 121 was made from sour sap obtained on April 21, after the buds were beginning to show considerable green. The sap was cloudy but not excessively so. The sirup contained 93.94% sucrose and 0.34% invert sugar. The color was 7, flavor 5, and score 450; depreciation from control (number 122), color 2, flavor 0, and score 50; depreciation from the first run control of the season (number 89), color 4, flavor 3, score 450.

122. Number 122 was made from sap obtained from the same tree as 121 and at the same time but from the fresh tap-hole. The sirup contained 95.80% sucrose and 0.67% invert sugar. The color was 5, flavor 5, and score 500; depreciation from first run control, color 2, flavor 3, and score 400.

123. Number 123 was made from sap obtained April 24 from a sour tap-hole. The sirup contained 95.33% sucrose and 0.64% invert sugar. The color was 11, flavor 6, and score 250; depreciation from control (number 124), color 6, flavor 1, and score 250; depreciation from first run control, color 8, flavor 4, and score 650.

124. Number 124 was made from sap obtained from the same tree and at the same time as that for 123, but from a fresh tap-hole. It contained 98.54% sucrose and 0.59% invert sugar. The color was 5, flavor 5, and score 500; depreciation from first run control, color 2, flavor 3, and score 400.

125. Number 125 was made from sour sap obtained from the tree April 24. It contained 93.88% sucrose and 0.53% invert sugar. The color was 7, flavor 5, and score 450; depreciation from control (number 126), color 1, flavor 0, and score 25; depreciation from first run control, color 4, flavor 3, and score 450.

126. Number 126 was obtained from the same tree and at the same time as number 125, but from a fresh tap-hole. The sirup contained 94.46% sucrose and 0.31% invert sugar. The color was 6, flavor 5, and score 475; depreciation from first run control, color 3, flavor 3, and score 425.

127. Number 127 was made from sour sap obtained April 27. The sirup contained 87.41% sucrose and 4.59% invert sugar. The color was 15, flavor 6, and score 150; depreciation from control (number 128), color 11, flavor 1, and score 375; depreciation from first run control, color 12, flavor 4, and score 750.

128. Number 128 was made from sap obtained from the same tree at the same time as that for 127 but from a fresh tap-hole. The sirup contained 94.21% sucrose and 0.31% invert sugar. The color was 4, flavor 5, and score 525; depreciation from first run control, color 1, flavor 3, and score 375.

129. Number 129 was obtained from a fresh tap-hole April 28. It contained 95.34% sucrose and 0.12% invert sugar. The color was 5, flavor 5, and score 500; depreciation from first run control, color 2, flavor 3, and score 400.

130. Number 130 was made from sap obtained from the same tree and at the same time as that for 129, but from the sour tap-hole. It contained 93.86% sucrose and 1.34% invert sugar. The color was 12, flavor 6, and score 225; depreciation from control (number 129), color 7, flavor 1, and score 275; depreciation from first run control, color 9, flavor 4, and score 675.

The results of this series of experiments confirm those obtained the previous year, indicating that, accompanying the resumption of vegetative activity in the tree, there is a change in sap which makes it impossible thereafter to produce sirups of superior flavor.

STATISTICAL SUMMARY OF FIELD EXPERIMENTS

For the sake of convenient reference a summary of the statistical data presented in the preceding pages is appended in tabular form and in numerical order (table 9). The number of the sample, the character of the organism employed or of the sample, the designation of the organism, the bacterial count per cc. of the sap, and the reaction of the sap in percent of N/100 acid occupy the first five columns respectively. These are followed by the percentages of sucrose and invert sugar in the sirups, calculated to a dry matter basis. The numbers in the column headed "ratio" were obtained by dividing the percent of sucrose by the percent of invert sugar. A small ratio number, therefore, indicates a relatively high proportion of invert sugar and a high number, a small proportion. The ratio numbers with their corresponding invert sugar values are shown below in tabular form:

Ratio numbers	Invert sugar values
1 to 5	above 15 %
5 " 10	15 % to $8\frac{1}{2}\%$
10 " 20	$8\frac{1}{2}\%$ " $4\frac{1}{2}\%$
20 " 50	$4\frac{1}{2}\%$ " 2 %
50 " 90	2 % " 1 %
90 " 180	1 % " $\frac{1}{2}\%$
180 " 400	$\frac{1}{2}\%$ " $\frac{1}{4}\%$
above 400	below $\frac{1}{4}\%$

Following the ratio column are given the values for color, flavor and score, assigned to the various sirups, and also the depreciation in color, flavor and score of inoculated sirups from the corresponding value assigned to their respective controls. A date column completes the table.

TABLE 9. TABULAR SUMMARY OF STATISTICAL DATA

No.	Character of sample or organism	Organism number	Count	Reaction	Sucrose
1	Control,				96.84
2	Fluorescent,	XXXIII			96.79
3	Ditto,	XXXVI			96.73
4	Ditto,	L			96.54
5	Ditto,	LIII			97.16
6	Control,				95.41
7	Fluorescent,	LVI			96.16
8	Ditto,	5			97.14
9	Non-fluorescent,	XXVI			95.61
10	Ditto,	XXX			95.86
11	<i>B. acris</i> ,	LXXXVII		170.0	96.12
12	Stringy peas,	I			95.71
13	Gray yeast,	24			93.34
14	Red yeast,	25		9.0	95.30
15	Ditto,	LXII		5.0	93.26
16	Penicillium,	LXIV		8.2	95.73
17	Ditto,	LXV		8.0	92.76
18	Red yeast,	LXXIX		12.0	91.65
19	Composite,			5.0	93.28
20	Control,			2.0	95.37
21	Last run, sweet,				95.19
22	Ditto, sour,				95.27
23	Ditto, sour				92.56
24	Ditto, sweet,				96.02
25	Ditto, sour,				94.05
26	Ditto, sweet,				96.42
27	Control,		10000		96.19
28	Gray yeast,	24	437000		82.83
29	Fluorescent,	CXXXIX	12350000		94.91
30	Ditto,	CLIX	3262000		93.75
*31	Gray yeast,	CXXI	5667000		96.62
*32	Ditto,	CLXXX	5600000		95.91
*33	Ditto,	CLXVIII	1950000		95.61
34	Control, 40°		7312000		95.86
35	Red yeast,	CXL	2255000		95.13
*36	Ditto,	CII	7312000		96.16
*37	Ditto,	CLXXV	8825000		95.88
38	Control, 80°		162500		94.80
*39	Gray yeast,	C	9750000		96.18
40	Incubator control,		5850000		95.05
41	Control,		66	1.2	97.82
42	Red yeast,	CVII	13650000	19.0	93.27
43	Control, 100°		1625000	6.5	94.19
44	Fluorescent,	CXLVIII	9000000	10.0	93.03
45	Incubator control,		19500	4.5	96.28
46	Pink coccus,	CIV	14300000	10.0	95.07

*Infection failed.

TABLE 9. TABULAR SUMMARY OF STATISTICAL DATA

DEPRECIATION									
Inv.	Sug.	Ratio	Color	Flavor	Score	Color	Flavor	Score	Date
1.07	90	7	1	850	1	0	25	3-24-09	
1.55	62	14	4	425	8	3	450	"	
2.09	46	11	2	700	5	1	175	"	
1.56	62	9	2	750	3	1	125	"	
1.44	67	11	2	700	5	1	175	"	
0.97	98	6	1	875				"	
1.64	59	10	2	725	4	1	150	3-27-09	
1.15	84	10	2	725	4	1	150	"	
0.78	122	5	2	850	-1	1	25	"	
0.77	124	6	3	750	0	2	125	"	
1.72	56	7	4	600	1	3	275	"	
2.23	43	6	3	750	0	2	125	"	
2.53	37	7	2	800	1	1	75	4- 1-09	
3.01	32	10	2	725	4	1	150	"	
2.98	31	8	2	775	2	1	100	"	
2.61	37	10	4	525	4	3	350	"	
3.47	27	10	2	725	4	1	150	"	
3.12	29	10	2	725	4	1	150	"	
4.09	23	9	3	675	3	2	200	"	
1.58	60	6	1	875				"	
0.82	116	3	1	950				4-12-09	
2.76	35	8	3	700	5	2	250	"	
3.55	26	14	3	550	7	2	300	"	
0.61	157	7	1	850				"	
3.13	30	14	3	550	9	2	350	4-16-09	
0.51	189	5	1	900				"	
0.30	321	4	2	875				3- 7-10	
12.15	7	11	4	500	7	2	375	"	
0.38	250	8	2 ¹	750	4	0 ¹	125	"	
0.89	105	8	2	775	4	0	100	"	
0.30	322	6	2	825	2	0	50	"	
0.46	208	6	2	825	2	0	50	"	
0.23	416	7	2	800	2	0	75	"	
0.42	228	6	2 ¹	800	2	0 ¹	75	"	
1.15	83	12	2 ¹	650	8	0 ¹	225	"	
0.61	158	9	2 ¹	725	5	0 ¹	150	"	
0.64	150	11	2 ¹	675	7	0 ¹	200	"	
0.48	198	5	2 ¹	825	1	0 ¹	50	"	
0.26	370	7	2	800	3	0	75	"	
0.64	149	9	2	750	5	0	125	"	
0.45	217	4	1	925				3-14-10	
2.14	44	5	2 ²	800	1	1 ¹	125	"	
2.64	36	7	2	800	3	1	125	"	
1.40	67	9	3	675	5	2	250	"	
0.51	189	4	1	925	0	0	0	"	
1.05	91	6	2	825	2	1	100	"	

TABLE 9—Continued

No.	Character of sample or organism	Organism number	Count	Reaction	Sucrose
47	Pink coccus,	IV	1950000	9.6	88.81
48	Gray yeast,	CLXXX	1625000	16.7	93.89
49	Control,	100	1.0	96.51	
50	Pink coccus,	XLIX	1950000	8.0	93.83
51	Ditto,	CVI	4225000	3.5	97.30
52	Gray yeast,	CLXII	1275000	6.0	96.84
53	Ditto,	CLXXI	630000	6.0	92.13
54	Pink coccus,	CXXVI	1300000	8.5	94.11
55	Non-fluorescent,	CVIII	2730000	6.0	94.76
56	Control, 100°	320000	3.1	96.02	
57	Incubator control,	37000	2.5	96.47	
58	Control,	380	3.0	97.01	
59	Red yeast,	CXXIII	325000	8.0	94.74
60	Ditto,	CXIII	1950000	8.4	95.44
61	Ditto,	CX	650000	5.5	95.80
62	Ditto,	25	650000	9.5	89.27
63	Ditto,	CXIV	975000	11.0	89.06
64	Ditto,	CXX	975000	10.0	91.64
65	Incubator control,	1950000	9.0	91.89	
66	Tin buckets,	140	2.0	96.62	
67	Wood buckets,	6500000	5.5	88.25	
68	Control	500	2.5	96.90	
69	Fluorescent,	CLIV	19500000	10.0	93.87
70	Ditto,	CXXXIII	20400000	10.0	93.47
71	Ditto,	CXLVII	23400000	6.5	93.69
72	Ditto,	CLIII	29250000	10.0	95.07
73	Ditto,	CLVIII	23400000	2.3	97.47
*74	Control burned,	750	3.0	96.36	
*75	Fluorescent,	CLXXIX	10400000	10.0	84.74
*76	Ditto,	CLV	4875000	10.7	87.03
*77	Ditto,	CLXXVII	11700000	10.1	88.13
*78	Ditto,	XXXVI	14625000	11.2	83.86
*79	Non-fluorescent,	CLXIII	6500000	25.4	78.78
*80	Pink yeast,	CLXXVIII	9750000	12.5	79.20
*81	Incubator control,	3250000	10.0	89.23	
†82	Sour sap,				
†83	Ditto,		43875000	6.0	
84	Sour sap kept,				91.14
85	Ditto,		11275000	6.0	94.64
86	Ditto,		11275000	6.0	93.21
87	Last run, fresh,	5	2.5	97.27	
88	Ditto, sour,	73125000	4.0	94.56	
89	Control,			1.2	95.81
90	<i>B. acris</i> ,	CCXVII		25.4	86.72
91	Fluorescent,	CXL		1.5	94.76

*A spore bearing organism with inverting power was present in association with the introduced species.

†82 and 83, made into sugar.

TABLE 9—Continued

Inv. Sug. Ratio	Color	Flavor	Score	DEPRECIATION			Date	
				Color	Flavor	Score		
7.90	11	6	3	750	2	2	175	3-14-10
2.35	40	6	2 ²	775	2	1 ²	150	"
0.42	230	2	1	975				3-20-10
2.20	43	6	2 ¹	800	4	1 ¹	175	"
0.65	150	4	2	875	2	1	100	"
1.21	80	5	2	850	3	1	125	"
3.96	23	6	3	750	4	2	225	"
2.71	35	7	2 ²	750	5	1 ²	225	"
2.38	40	5	2	850	3	1	125	"
1.35	71	5	2	850	3	1	125	"
0.60	161	2	1	975	0	0	0	"
0.43	226	3	1	950				3-21-10
2.03	47	7	3	725	4	2	225	"
1.76	54	6	3	750	3	2	200	"
1.77	54	9	3	675	6	2	275	"
7.30	12	9	4	550	6	3	400	"
7.63	12	8	3	700	5	2	250	"
5.86	16	8	3	700	5	2	250	"
3.52	26	6	4	625	3	3	325	"
0.41	236	3	1	950				3-22-10
6.91	13	9	4	550	6	3	400	3-24-10
0.51	190	4	1	925				3-22-10
1.59	59	9	3	675	5	2	250	"
2.46	38	11	4	500	7	3	425	"
0.58	162	14	4	425	10	3	500	"
0.87	109	13	4	450	9	3	475	"
0.68	143	6	2	825	2	1	100	"
0.70	138	9	4	550	5	3	375	3-24-10
10.77	8	9	3	675	5	2	250	"
8.94	10	10	3	650	6	2	275	"
8.24	11	8	3	700	4	2	225	"
10.48	8	8	4	575	4	3	350	"
15.25	5	7	4	600	3	3	325	"
16.13	5	10	4	525	6	3	400	"
7.51	12	7	4	600	3	3	325	"
								3-29-10
								4- 2-10
2.83	32	20	3 ¹	350				"
1.57	60	20*	3 ¹	325				"
1.23	76	20*	3 ¹	325				"
0.26	374	4	5	525				4- 3-10
1.79	53	11	6	250	7	1	275	"
0.34	282	3	2	900				3-22-11
7.20	12	7	4	600	4	2	300	"
0.40	237	6	3	750	3	1	150	"

*A spore bearing organism with inverting power was present in association with the introduced species.

TABLE 9—Concluded

No.	Character of sample or organism	Organism number	Count	Reaction	Sucrose
92	Fluorescent,	CXII		1.4	95.00
93	Ditto,	LI		1.2	95.43
94	Ditto,	CXLI		1.2	94.68
95	<i>B. aceris</i> ,	LXXXVII		27.0	90.85
96	Incubator control,			0.5	95.33
97	Control,			0.5	96.04
98	Pink yeast,	CXXXII		1.5	86.70
99	Red yeast,	CX		1.4	94.82
100	Fluorescent,	CXLVIII		1.1	96.21
101	Ditto,	5		1.2	96.45
102	Ditto,	XXXIII		4.5	95.67
103	Ditto,	XXXVI		1.4	95.38
104	Incubator control,			0.6	97.00
105	Control,			1.0	96.23
†106	Red yeast,	CCIII		4.1	97.30
107	Pink coccus,	CVI		4.0	94.52
†108	Pink yeast,	CLXXXVIII		3.3	95.37
109	Gray yeast,	24		41.0	67.33
110	Ditto,	CXXI		3.3	97.09
111	Eurotium,	CCCI		2.0	93.31
112	Incubator control,			1.0	97.60
113	Control,			2.0	96.97
114	Red yeast,	LXII		5.0	96.31
115	Gray yeast,	CXXI		4.7	95.14
116	Composite,	{ LXII			
		{ CXLV		3.7	95.62
117	Eurotium,	CCCI		7.4	91.09
118	Composite,	{ CXXI			
		{ CXLV		4.8	95.69
119	Composite,	{ CCCI			
		{ CXLV		4.2	96.27
120	Incubator control,			6.4	95.02
121	Last run sour				93.94
122	Ditto, sweet				95.80
123	Ditto, sour				95.33
124	Ditto, sweet				98.54
125	Ditto, sour				93.88
126	Ditto, sweet				94.46
127	Ditto, sour				87.41
128	Ditto, sweet				94.21
129	Ditto, sweet				95.34
130	Ditto, sour				93.86

†106 and 108, infection failed.

TABLE 9—*Concluded*

Inv. Sug.	Ratio	Color	Flavor	Score	DEPRECIATION			Date
					Color	Flavor	Score	
0.52	183	7	3	725	4	1	175	3-22-11
0.43	222	6	2	825	3	0	75	"
0.52	182	7	4	600	4	2	300	"
5.04	18	6	3	750	3	1	150	"
0.44	217	5	2	850	2	0	50	"
0.19	505	3	1	950				3-26-11
8.69	10	9	4	550	6	3	400	"
2.05	46	7	4	600	4	3	350	"
0.93	103	7	3	725	4	2	225	"
0.94	103	8	3	700	5	2	250	"
1.14	84	7	4	600	4	3	350	"
1.35	71	7	4	600	4	3	350	"
0.41	237	4	2	875	1	1	75	"
0.24	403	3	2	900				3-27-11
0.66	147	7	3	725	4	1	175	"
0.69	137	5	4	650	2	2	250	"
0.90	106	4	3	800	1	1	100	"
28.35	2	10	4	525	7	2	375	"
1.74	56	6	4	625	3	2	275	"
4.39	21	7	4	600	4	2	300	"
1.11	88	5	2	850	2	0	50	"
0.61	159	4	2	875				3-30-11
1.01	95	5	3	775	1	1	100	"
1.52	63	7	4	600	3	2	275	"
0.68	141	8	4	575	4	2	300	"
3.72	25	9	4	550	5	2	325	"
0.98	98	7	4	600	3	2	275	" *
0.81	119	7	2	800	3	0	75	"
0.57	167	5	3	775	1	1	100	" *
0.34	276	7	5	450	2	0	50	4-21-11
0.67	143	5	5	500				"
0.64	149	11	6	250	6	1	250	4-24-11
0.59	167	5	5	500				"
0.53	125	7	5	450	1	0	25	"
0.31	305	6	5	475				"
4.59	19	15	6	150	11	1	375	4-27-11
0.31	304	4	5	525				"
0.12	794	5	5	500				4-28-11
1.34	70	12	6	225	7	1	275	"

DISCUSSION OF RELATED SIRUPS IN GROUPS

A survey of the preceding table shows that the sirups naturally fall into different groups according to the character of the sap used or of the treatment accorded to it. For convenient study and discussion the tables have been re-arranged so as to bring similar samples together in groups.

It appeared in the discussion of individual samples that the inoculation failed in certain instances. Such samples have been placed by themselves and are grouped together without regard to the character of the organisms with which inoculation was attempted. In one series a spore-bearing organism became at least equally as important as the bacteria which were artificially introduced, and this series has been treated as a unit in the re-arrangement. The samples inoculated with yeasts and molds showed a tendency to mixed infection in which the fluorescent organisms naturally present played a more or less important part. With the other statistical data in the following tables, the average color, flavor and score for each group, as well as the average depreciation of color, flavor and score, is recorded at the foot in the proper columns.

Twenty-two sirups were made from sap successfully inoculated with one or another strain of fluorescent bacteria. The average color was 9, flavor 2.9, and score 665; the average depreciation from control, color 4.8, flavor 1.6, and score 242.

Four samples were successfully inoculated with non-fluorescent bacteria. The average color was 5.5, flavor 2.5, and score 800; the average depreciation from control, color 0.5, flavor 2.5, and score 100.

Seven samples were influenced by the action of a spore-bearing organism of the subtilis type which appeared spontaneously. Four of these were inoculated with fluorescent organisms, one with a non-fluorescent bacillus similar to the intruder, and one with a pink yeast which was not recovered, while the other was intended for an incubator control. It is evident that the quality of these sirups must be attributed to the combined action of the two groups of organisms. The average color was

8.4, flavor 3.6, and score 618; the average depreciation from control, color 4.4, flavor 2.6, and score 307.

Three sirups were made from sap successfully inoculated with *Bacillus aceris*, a stringy sap organism, of which two strains were employed. The average color was 6.7, flavor 3.7 and score 650; the average depreciation from control, color 2.7, flavor 2, and score 242.

Six samples were inoculated with pink cocci belonging to the *Micrococcus rosus* type. The average color was 5.7, flavor 2.6, and score 775; the average depreciation from control, color 2.8, flavor 1.6, and score 171.

Only one sample was successfully inoculated with pink yeast.

Thirteen samples were inoculated with red yeast with at least partial success. The fluorescent bacteria developed in association with the introduced organisms in a considerable number of these samples, so that the quality of sirup secured must be assigned to the combined activities of the two species. The average color was 8, flavor 2.8, and score 703; the average depreciation from control, color 4.1, flavor 1.7, and score 215.

Eight samples were inoculated with gray yeast with partial or complete success. Here again the fluorescent bacteria sometimes developed in association with the yeasts and the results must be regarded as the product of the activities of both classes of organisms. The average color was 7.3, flavor 3.2, and score 678; the average depreciation from control, color 3.8, flavor 1.7, and score 234.

Four samples were successfully inoculated with green mold. In two instances *Penicillium* was employed and in the others, *Eurotium*. Fluorescent bacteria played a part as associated organisms in certain of these samples. The average color was 9, flavor 3.5, and score 600; average depreciation from control, color 4.8, flavor 2.0, and score 281.

Four sirups were made from saps inoculated with a mixture of organisms. The composite infection was undertaken to determine the influence of yeasts and molds upon the development of fluorescent bacteria. The results were not entirely satisfactory

but indicate that when these two groups of organisms are associated in the same sample of sap the fluorescent bacteria are likely to gain the ascendancy. The appearance of the samples and the results of the plates indicated that the development of the fluorescent group was stimulated by the presence of yeasts and molds, with which they must compete. This may account for the considerable number of failures which resulted from attempts to inoculate unsterilized sap with cultures of yeasts and molds. The average figures for the composite samples follow: Color 7.7, flavor 3, and score 663; the average depreciation from control, color 3.3, flavor 1.5, and score 213.

In eight cases, attempts at infection failed or at least the introduced organism was not recovered. In a majority of these samples the fluorescent bacteria appeared sooner or later and exercised an influence upon the quality of the sirup. The average color was 7, flavor 2.3, and score 772; average depreciation from control, color 3.4, flavor 0.3, and score 103.

Three sirups were made from natural sour sap, that is to say, sap which was allowed to remain in the buckets late in the season until it had seriously depreciated. One object of this procedure was to determine what proportion of invert sugar might be expected in such material. Difficulty is often experienced in graining sugar made from the last run sirups. This trouble probably results from a large proportion of invert sugar, which of course might be formed in the sap by the action of micro-organisms. In the three sirups here reported, however, the proportion of invert sugar was low. Two other samples of similar material yielded sugar which grained readily. The average figures for the three sirups follow: color 20+, flavor 3¹, and score 333; average depreciation calculated on first run control, color 16+, flavor 1¹, and score 542.

Thirteen samples were reserved for incubator controls. These were treated in different ways in different series. Some of them were so handled that they were only slightly inferior to the true control, while in other instances they were very nearly comparable to inoculated material. The greater part of the depreciation in

these samples should be attributed to the fluorescent group of bacteria. The average color was 5.4, flavor 2, and score 827; average depreciation, color 1.8, flavor 0.7, and score 87.

Eleven samples were reserved as controls. Part of these were held in the cold during the incubation period and undoubtedly underwent slight depreciation. The average color was 3.8, flavor 1.4, and score 911.

Nine samples were made from last run sap obtained from tap-holes which had become sour, that is from which cloudy sap was running. The average color was 11, flavor 4.8, and score 397; average depreciation from the first run control of the same season, color 6.9, flavor 3.1, and score 490.

Nine samples were made from last run material obtained from the same trees and at the same time as the nine samples mentioned in the preceding paragraph, but from fresh tap-holes. It is important to notice that the first three samples of this character which were made in 1909 possessed a flavor equal to that of the first run control, and that two of these same sirups were superior in color to their control. In the remaining six instances, however, the product of the two succeeding seasons, the sirups possessed the characteristic buddy flavor and were uniformly 3 grades inferior to the controls. The average color was 5, flavor 3.7, and score 636; average depreciation from first run control of the same season, color 0.8, flavor 2, and score 243.

If the nine samples of sirups obtained from the sour sap of the last run are compared with the nine samples obtained from the sweet sap of the last run, it is seen that the average depreciation from souring is 6.1 in color, 1.1 in flavor, and 239 in score.

One sirup was made from sap caught in tin buckets under cleanly conditions, and one was made from sap obtained the following days from the same tree but caught in wooden buckets. This latter sample showed a depreciation of 6 points in color, 3 in flavor, and 400 in score.

In addition to the groups mentioned above one sirup originally intended for a control was burned so that it was necessary to eliminate it from the comparison. The tabulated results follow:

TABLE 10. STATISTICAL TABLES SHOWING RELATED SAMPLES IN JUXTAPOSITION

No.	Character of sample or organism	Organism number	Count	Reaction	Sucrose
2	Fluorescent,	XXXIII			96.79
102	Ditto,	Ditto,		4.5	95.67
3	Ditto,	XXXVI			96.73
103	Ditto,	Ditto,		1.4	95.38
4	Ditto,	L			96.54
5	Ditto,	LIII			97.16
7	Ditto,	LVI			96.16
8	Ditto,	5			97.14
101	Ditto,	5		1.2	96.45
29	Ditto,	CXXXIX	12350000		94.91
30	Ditto,	CLIX	3262000		93.75
44	Ditto,	CLXVIII	9000000	10.0	93.03
100	Ditto,	Ditto,		1.1	96.21
69	Ditto,	CLIV	19500000	10.0	93.87
70	Ditto,	CXXXIII	20400000	10.0	93.47
71	Ditto,	CXLVII	23400000	6.5	93.69
72	Ditto,	CLIII	29250000	10.0	95.07
73	Ditto,	CLVIII	23400000	2.3	97.47
91	Ditto,	CXL		1.5	94.76
92	Ditto,	CXII		1.4	95.00
93	Ditto,	LI		1.2	95.43
94	Ditto,	CXLI		1.2	94.68
	Average,				
9	Non-fluorescent,	XXVI			95.61
10	Ditto,	XXX			95.86
12	Ditto,	I			95.71
55	Ditto,	CVIII	2730000	6.0	94.76
	Average,				
75	Spore-bearer plus*	CLXXIX	10400000	10.0	84.74
76	Ditto,	CLV	4875000	10.7	87.03
77	Ditto,	CLXXVII	11700000	10.1	88.13
78	Ditto,	XXXVI	14625000	11.2	83.86
79	Ditto,	CLXIII	6500000	25.4	78.74
80	Ditto,	CLXXVIII	9750000	12.5	79.20
81	Ditto,		3250000	10.0	89.23
	Average,				
11	<i>B. aceris</i> ,	LXXXVII		170.0	96.12
95	Ditto,	Ditto,		27.0	90.85
90	Ditto,	CCXVII		25.4	86.72
	Average,				

*I. e., spore-bearing organisms associated with fluorescent and other organisms. (See pages 375 to 377.)

TABLE 10. STATISTICAL TABLES SHOWING RELATED SAMPLES IN JUXTAPOSITION

DEPRECIATION									
Inv.	Sug.	Ratio	Color	Flavor	Score	Color	Flavor	Score	Date
1.55	62	14	4	425	8	3	450	3-24-09	
1.14	84	7	4	600	4	3	350	3-26-11	
2.09	46	11	2	700	5	1	175	3-24-09	
1.35	71	7	4	600	4	3	350	3-26-11	
1.56	62	9	2	750	3	1	125	3-24-09	
1.44	67	11	2	700	5	1	175	"	
1.64	59	10	2	725	4	1	150	3-27-09	
1.15	84	10	2	725	4	1	150	"	
0.94	103	8	3	700	5	2	250	3-26-11	
0.38	250	8	2 ¹	750	4	0 ¹	125	3- 7-10	
0.89	105	8	2	775	4	0	100	"	
1.40	67	9	3	675	5	2	250	3-14-10	
0.93	103	7	3	725	4	2	225	3-26-11	
1.59	59	9	3	675	5	2	250	3-22-10	
2.46	38	11	4	500	7	3	425	"	
0.58	162	14	4	425	10	3	500	"	
0.87	109	13	4	450	9	3	475	"	
0.68	143	6	2	825	2	1	100	"	
0.40	237	6	3	750	3	1	150	3-22-11	
0.52	183	7	3	725	4	1	175	"	
0.43	222	6	2	825	3	0	75	"	
0.52	182	7	4	600	4	2	300	"	
		9	2.9	665	4.8	1.6	242		
0.78	122	5	2	850	—1	1	25	3-27-09	
0.77	124	6	3	750	0	2	125	"	
2.23	43	6	3	750	0	2	125	"	
2.38	40	5	2	850	3	1	125	3-20-10	
		5.5	2.5	800	0.5	1.5	100		
10.77	8	9	3	675	5	2	250	3-24-10	
8.94	10	10	3	650	6	2	275	"	
8.24	11	8	3	700	4	2	225	"	
10.45	8	8	4	575	4	3	350	"	
15.25	5	7	4	600	3	3	325	"	
16.13	5	10	4	525	6	3	400	"	
7.51	12	7	4	600	3	3	325	"	
		8.4	3.6	618	4.4	2.6	307		
1.72	56	7	4	600	1	3	275	3-27-09	
5.04	18	6	3	750	3	1	150	3-22-11	
7.20	12	7	4	600	4	2	300	"	
		6.7	3.7	650	2.7	2	242		

TABLE 10-Continued

No.	Character of sample or organism	Organism number	Count	Reaction	Sucrose
46	Pink coccus,	CIV	14300000	10.0	95.07
47	Ditto,	IV	1950000	9.6	88.81
50	Ditto,	XLIX	1950000	8.0	93.83
51	Ditto,	CVI	4225000	3.5	97.30
107	Ditto,	Ditto,		4.0	94.52
54	Ditto,	CXXVI	1300000	8.5	94.11
	Average,				
98	Pink yeast,	CXXXII		1.5	86.70
14	Red yeast,	25		9.0	95.30
62	Ditto,	Ditto,	650000	9.5	89.27
15	Ditto,	LXII		5.0	93.26
114	Ditto,	Ditto,		5.0	96.31
18	Ditto,	LXXIX		12.0	91.65
35	Ditto,	CXI	2255000		95.13
42	Ditto,	CVII	13650000	19.0	93.27
59	Ditto,	CXXIII	325000	8.0	94.74
60	Ditto,	CXIII	1950000	8.4	95.44
61	Ditto,	CX	650000	5.5	95.80
99	Ditto,	Ditto,		1.4	94.82
63	Ditto,	CXIV	975000	11.0	89.06
64	Ditto,	CXX	97500	10.0	91.64
	Average,				
13	Gray yeast,	24			93.34
28	Ditto,	Ditto,	437000		82.83
109	Ditto,	Ditto,		41.0	67.33
48	Ditto,	CLXXX	1625000	16.7	93.89
52	Ditto,	CLXII	1275000	6.0	96.84
53	Ditto,	CLXXI	630000	6.0	92.13
110	Ditto,	CXXI		3.3	97.09
115	Ditto,	Ditto		4.7	95.14
	Average,				
16	Green mold,	LXIV		8.2	95.73
17	Ditto,	LXV		8.0	92.76
111	Ditto,	CCCI		2.0	93.31
117	Ditto,	Ditto,		7.4	91.09
	Average,				
19	Composite,			5.0	93.28
116	Ditto,			3.7	95.62
118	Ditto,			4.8	95.69
119	Ditto,			4.2	96.27
	Average,				

TABLE 10—Continued

Inv. Sug.	Ratio	Color	Flavor	Score	DEPRECIATION			Date
					Color	Flavor	Score	
1.05	91	6	2	825	2	1	100	3-14-10
7.90	11	6	3	750	2	2	175	"
2.20	43	6	2 ¹	800	4	1 ¹	175	3-20-10
0.65	150	4	2	875	2	1	100	"
0.69	137	5	4	650	2	2	250	3-27-11
2.71	35	7	2 ³	750	5	1 ¹	225	3-20-10
		5.7	2.6	775	2.8	1.6	171	
8.69	10	9	4	550	6	3	400	3-26-11
3.01	32	10	2	725	4	1	150	4- 1-09
7.30	12	9	4	550	6	3	400	3-21-10
2.98	31	8	2	775	2	1	100	4- 1-09
1.01	95	5	3	775	1	1	100	3-30-11
3.12	29	10	2	725	4	1	150	4- 1-09
1.15	83	12	2 ¹	650	8	0 ¹	225	3- 7-10
2.14	44	5	2 ³	800	1	1 ¹	125	3-14-10
2.03	47	7	3	725	4	2	225	3-21-10
1.76	54	6	3	750	3	2	200	"
1.77	54	9	3	675	6	2	275	"
2.05	46	7	4	600	4	3	350	3-26-11
7.63	12	8	3	700	5	2	250	3-21-10
5.86	16	8	3	700	5	2	250	"
		8	2.8	703	4.1	1.7	215	
2.53	37	7	2	800	1	1	75	4- 1-09
12.15	7	11	4	500	7	2	375	3- 7-10
28.35	2	10	4	525	7	2	375	3-27-11
2.35	40	6	2 ¹	775	2	1 ¹	150	3-14-10
1.21	80	5	2	850	3	1	125	3-20-10
3.96	23	6	3	750	4	2	225	"
1.74	56	6	4	625	3	2	275	3-27-11
1.52	63	7	4	600	3	2	275	3-30-11
		7.3	3.2	678	3.8	1.7	234	
2.61	37	10	4	525	4	3	350	4- 1-09
3.47	27	10	2	725	4	1	150	"
4.39	21	7	4	600	4	2	300	3-27-11
3.72	25	9	4	550	5	2	325	3-30-11
		9	3.5	600	4.3	2	281	
4.09	23	9	3	675	3	2	200	4- 1-09
0.68	141	8	4	575	4	2	300	3-30-11
0.98	98	7	4	600	3	2	275	"
0.81	119	7	2	800	3	0	75	"
		7.7	3	663	3.3	1.5	213	

TABLE 10—*Continued*

No.	Character of sample or organism	Organism number	Count	Reaction	Sucrose
31	Failure,		5667000		96.62
32	Ditto,		5600000		95.91
33	Ditto,		1950000		95.61
36	Ditto,		7312000		96.16
37	Ditto,		8825000		95.88
39	Ditto,		9750000		96.18
106	Ditto,			4.1	97.30
108	Ditto,			3.3	95.37
	Average,				
84	Sour sap kept,				91.14
85	Ditto,		11275000	6.0	94.68
86	Ditto,		11275000	6.0	93.21
	Average,				
Depreciation on foregoing calculated on first run control.					
1	Incubator control,				96.84
34	Ditto,		7312000		95.86
38	Ditto,		162500		94.80
40	Ditto,		5850000		95.05
43	Ditto,		1625000	6.5	94.19
45	Ditto,		19500	4.5	96.28
56	Ditto,		320000	3.1	96.02
57	Ditto,		37000	2.5	96.47
65	Ditto,		1950000	9.0	91.89
96	Ditto,			0.5	95.33
104	Ditto,			0.6	97.00
112	Ditto,			1.0	97.60
120	Ditto,			6.4	95.02
	Average,				
6	Control,				95.41
20	Ditto,			2.0	95.37
27	Ditto,		10000		96.19
41	Ditto,		66	1.2	97.82
49	Ditto,		100	1.0	96.51
58	Ditto,		380	3.0	97.01
68	Ditto,		500	2.5	96.90
89	Ditto,			1.2	95.81
97	Ditto,			0.5	96.04
105	Ditto,			1.0	96.23
113	Ditto,			2.0	96.97
	Average,				

TABLE 10—Continued

Inv. Sug.	Ratio	Color	Flavor	Score	DEPRECIATION			Date
					Color	Flavor	Score	
0.30	322	6	2	825	2	0	50	3- 7-10
0.46	208	6	2	825	2	0	50	"
0.23	416	7	2	800	3	0	75	"
0.61	158	9	2 ¹	725	5	0 ¹	150	"
0.64	150	11	2 ¹	675	7	0 ¹	200	"
0.26	370	7	2	800	3	0	75	"
0.66	147	7	3	725	4	1	175	3-27-11
0.90	106	4	3	800	1	1	100	"
		7	2.3	772	3.4	.3	103	
2.83	32	20	3 ¹	350	16	1 ¹	525	4- 2-10
1.57	60	20+	3 ¹	325	16+	1 ¹	550	"
1.23	76	20+	3 ¹	325	16+	1 ¹	550	"
		20	3 ¹	333	16	1 ¹	542	
1.07	90	7	1	850	1	0	25	3-24-09
0.42	228	6	2 ¹	800	2	0 ¹	75	3- 7-10
0.48	198	5	2 ¹	825	1	0 ¹	50	"
0.64	149	9	2	750	5	0	125	"
2.64	36	7	2	800	3	1	125	3-14-10
0.51	189	4	1	925	0	0	0	"
1.35	71	5	2	850	3	1	125	3-20-10
0.60	161	2	1	975	0	0	0	"
3.52	26	6	4	625	3	3	325	3-21-10
0.44	217	5	2	850	2	0	50	3-22-11
0.41	237	4	2	875	1	1	75	3-26-11
1.11	88	5	2	850	2	0	50	3-27-11
0.57	167	5	3	775	1	1	100	3-30-11
		5.4	2	827	1.8	.7	87	
0.97	98	6	1	875				3-24-09
1.58	60	6	1	875				4- 1-09
0.30	321	4	2	875				3- 7-10
0.45	217	4	1	925				3-14-10
0.42	230	2	1	975				3-20-10
0.43	226	3	1	950				3-21-10
0.51	190	4	1	925				3-22-10
0.34	282	3	2	900				3-22-11
0.19	505	3	1	950				3-26-11
0.24	403	3	2	900				3-27-11
0.61	159	4	2	875				3-30-11
		3.8	1.4	911				

TABLE 10—*Concluded*

No.	Character of sample or organism	Organism number	Count	Reaction	Sucrose
22	Last run sour,				95.27
23	Ditto,				92.56
25	Ditto,				95.05
88	Ditto,		73125000	4.0	94.56
121	Ditto,				93.94
123	Ditto,				95.33
125	Ditto,				93.88
127	Ditto,				87.41
130	Ditto,				93.86
Average,					
Depreciation on foregoing calculated on first run control.					
21	Last run sweet,				95.19
24	Ditto,				96.02
26	Ditto,				96.42
87	Ditto,		5	2.5	97.27
122	Ditto,				95.80
124	Ditto,				98.54
126	Ditto,				94.46
128	Ditto,				94.21
129	Ditto,				95.34
Average,					
Depreciation on foregoing calculated on first run control.					
22	Last run sour,				95.27
21	Ditto, sweet,				95.19
23	Ditto, sour,				92.56
24	Ditto, sweet,				96.02
25	Ditto, sour,				94.05
26	Ditto, sweet,				96.42
88	Ditto, sour,		73125000	4.0	94.56
87	Ditto, sweet,		5	2.5	97.27
121	Ditto, sour,				93.94
122	Ditto, sweet,				95.80
123	Ditto, sour,				95.33
124	Ditto, sweet,				98.54
125	Ditto, sour,				93.88
126	Ditto, sweet,				94.46
127	Ditto, sour,				87.41
128	Ditto, sweet,				94.21
130	Ditto, sour,				93.86
129	Ditto, sweet,				95.34
Average depreciation of sour samples,					
66	Tin bucket,		140	2.0	96.62
67	Wood bucket,		6500000	5.5	88.25
74	Burned control,		750	3.0	96.36

TABLE 10—*Concluded*

Inv. Sug.	Ratio	Color	Flavor	Score	DEPRECIATION			Date
					Color	Flavor	Score	
2.76	35	8	3	700	2	2	175	4-12-09
3.55	26	14	3	550	8	2	325	"
3.13	30	14	3	550	8	2	325	4-16-09
1.79	53	11	6	250	7	4	625	4- 3-10
0.34	276	7	5	450	4	3	450	4-21-11
0.64	149	11	6	250	8	4	650	4-24-11
0.53	125	7	5	450	4	3	450	"
4.59	19	15	6	150	12	4	750	4-27-11
1.34	70	12	6	225	9	4	675	4-28-11
		11	4.8	397	6.9	3.1	492	
0.82	116	3	1	950	-3	0	-75	4-12-09
0.61	157	7	1	850	1	0	25	"
0.51	189	5	1	900	-1	0	-25	4-16-09
0.26	374	4	5	525	0	3	250	4- 3-10
0.67	143	5	5	500	2	3	400	4-21-11
0.59	167	5	5	500	2	3	400	4-24-11
0.31	305	6	5	475	3	3	425	"
0.31	304	4	5	525	1	3	375	4-27-11
0.12	794	5	5	500	2	3	400	4-28-11
		5	3.7	636	.8	2	243	
2.76	35	8	3	700	5	2	250	4-12-09
0.82	116	3	1	950				"
3.55	26	14	3	550	7	2	300	"
0.61	157	7	1	850				"
3.13	30	14	3	550	9	2	350	4-16-09
0.51	189	5	1	900				"
1.79	53	11	6	250	7	1	275	4- 3-10
0.62	374	4	5	525				"
0.34	276	7	5	450	2	0	50	4-21-11
0.67	143	5	5	500				"
0.64	149	11	6	250	6	1	250	4-24-11
0.59	167	5	5	500				"
0.53	125	7	5	450	1	0	25	"
0.31	305	6	5	475				"
4.59	19	15	6	150	11	1	375	4-27-11
0.31	304	4	5	525				"
1.34	794	12	6	225	7	1	275	4-28-11
0.12	70	5	5	500				"
					6.1	1.1	239	
0.41	236	3	1	950				3-22-10
6.91	13	9	4	550	6	3	400	3-24-10
0.70	138	9	4	550	5	3	375	3-24-10

TABLE 11. SUMMARY OF AVERAGES OF RELATED GROUPS IN ORDER OF SCORE

No.	Group	Number of samples in group	Sucrose
1	Tin buckets,	1	96.62
2	Controls,	11	96.32
3	Incubator controls,	13	95.55
4	Non-fluorescent bacteria,	4	95.50
5	Pink cocci,	6	93.94
6	Failures,	8	96.13
7	Red yeasts,	13	93.54
8	Gray yeasts,	8	89.72
9	Fluorescent bacteria,	22	95.42
10	Composites,	4	95.22
11	<i>B. aceris</i> ,	3	91.16
12	Last run sweet,	9	95.92
13	Fluorescent and spore-bearing bacteria,	7	84.42
14	Green molds,	4	93.21
15	Pink yeast,	1	86.70
16	Wooden buckets,	1	88.25
17	Burned control,	1	96.36
18	Last run, sour,	9	93.41
19	Sour sap kept,	3	93.00

TABLE 11. SUMMARY OF AVERAGES OF RELATED GROUPS IN ORDER OF SCORE

Inv. Sug.	Ratio	Color	Flavor	Score	DEPRECIATION		
					Color	Flavor	Score
0.41	236	3.0	1.0	950			
0.60	161	3.8	1.4	911			
1.04	90	5.4	2.0	827	1.8	0.7	87
1.52	62	5.5	2.5	800	0.5	1.5	100
2.45	37	5.7	2.6	775	2.8	1.6	171
0.51	74	7.0	2.3	772	3.4	0.3	103
3.18	29	8.0	2.8	703	4.1	1.7	215
6.86	13	7.3	3.2	678	3.8	1.7	234
1.09	88	9.0	2.9	665	4.8	1.6	242
1.64	58	7.7	3.0	663	3.3	1.5	213
4.70	20	6.7	3.7	650	2.7	2.0	242
0.47	204	5.0	3.7	636	0.8	2.0	243
11.03	8	8.4	3.6	618	4.4	2.6	307
3.56	26	9.0	3.5	600	4.3	2.0	281
8.69	10	9.0	4.0	550	6.0	3.0	400
6.91	13	9.0	4.0	550	6.0	3.0	400
0.70	138	9.0	4.0	550	6.0	3.0	400
2.07	45	11.0	4.8	397	6.9	3.1	492
1.88	49	20.0	3 ¹ .	333	16.0	1 ¹ .	542

COMPARISON OF SIRUPS MADE FROM INOCULATED SAP AND FROM
NATURAL SOUR SAP

The reader with a practical turn of mind may well inquire how the quality of the sirups made from the inoculated saps compares with that of the sirups made from saps which have become sour from natural causes. It might seem that the artificial introduction of large numbers of bacteria into sap would result in the production of an abnormal sirup, far inferior to that secured from saps souring under natural, and perhaps unavoidable, conditions; but such is not the fact. Much sirup and sugar are annually made from sap more seriously injured by natural souring than was most of that discussed in the foregoing pages. The organisms at work are the same in either case, but the conditions under which souring occurs in nature are as a rule more favorable to bacterial growth than were those maintained in the incubator. In nature, however, there is almost always a mixed infection, in which the predominant forms are those most seriously injuring the color. In the incubator it was possible so to control conditions as to give the advantage to particular groups at will, so that in some cases the flavor of the sirup was more seriously injured than is likely to occur in nature unless the conditions are extremely bad. The writer, while unwilling to acknowledge himself a great offender, has personally made sirups for commercial sale from saps injured more seriously by natural souring than were most of those employed in these experiments. In fact only the most painstaking care can prevent the occurrence of such injury towards the close of the season.

The facts are brought out clearly by a study of the data already presented. Twelve of the sirups discussed were made from sap which had soured naturally. The average color was 8.3, flavor 4.3, and score 381; average depreciation from first run control, color 9.2, flavor 2.6, and score 504. Three of these samples, however, (Nos. 84, 85 and 86) were made from sour sap which had been allowed to stand two or three days in the buckets so that it was very poor indeed; and six (Nos. 88, 121, 123, 125,

127 and 130) were made from sour sap drawn very late in the season, so that it was not only sour but buddy. The three remaining samples (Nos. 22, 23 and 25), however, were made from sour sap free from buddy flavor. Samples 22 and 25 were concentrated to sirup the same day they flowed, and at the time of evaporation the first drops to run had not been out of the vascular tissue more than twelve hours. Sample 23 was evaporated thirty-six hours after it began to run. These sirups might be expected to be at least as good as the ordinary material made from sour sap and probably superior to it. They are therefore used in the following comparison of depreciation values, which values in these cases are calculated from the average of all controls of the three seasons, instead of from the average of first run controls. The average color was 12, flavor 3, and score 600; average depreciation from all controls, color 8.2, flavor 1.6, and score 311.

DISCUSSION OF DEPRECIATION VALUES

The specific influence of the various groups of organisms and of natural souring upon sirup is seen most clearly from a study of the depreciation values. If the groups are arranged according to the average amounts of depreciation in color they fall into the following order:

TABLE 12. ORDER OF AVERAGE DEPRECIATION IN COLOR

	Group	Depreciation	
		Color	Flavor
1	Non-fluorescent bacteria,	0.5	1.5
2	Incubator control,	1.8	0.7
3	<i>B. aceris</i> ,	2.7	2.0
4	Pink coccus,	2.8	1.6
5	Composites,	3.3	1.5
6	Failures,	3.4	0.3
7	Gray yeast,	3.8	1.7
8	Red yeast,	4.1	1.7
9	Green mold,	4.3	2.0
10	Fluorescent bacteria plus spore-bearers,	4.4	2.6
11	Fluorescent bacteria,	4.8	1.6
12	Natural sour sap,	8.2	1.6

A glance at the foot of the table shows that the sirups most seriously injured in color were made from sap souring naturally.

The sirups showing the next most serious depreciation in color were those inoculated with green fluorescent bacteria. Then comes a group in which fluorescent organisms were employed in the inoculation and developed in association with such spore-bearers as were present. It has already been shown that the fluorescent bacteria exercised some influence on the sirups of the next five groups also, while in the remaining groups they were either absent or present in smaller numbers for a shorter time.

If the depreciation figures are arranged according to flavor values a different order is secured, as follows:

TABLE 13. ORDER OF AVERAGE DEPRECIATION IN FLAVOR

	Group	Color	Depreciation	Score
			Flavor	
1	Failures,	3.4	0.3	103
2	Incubator control,	1.8	0.7	87
3	Non-fluorescent bacteria,	0.5	1.5	100
4	Composites,	3.3	1.5	213
5	Pink coccus,	2.8	1.6	171
6	Fluorescent bacteria,	4.8	1.6	242
7	<i>Natural sour sap</i> ,	8.2	1.6	311
8	Gray yeast,	3.8	1.7	234
9	Red yeast,	4.1	1.7	215
10	<i>B. aceris</i> ,	2.7	2.0	242
11	Green molds,	4.3	2.0	281
12	Fluorescent bacteria plus spore-bearers,	4.4	2.6	307

The spore-bearing bacteria, green molds, *B. aceris*, both groups of yeasts and the natural sour material, occupy positions in this table below the fluorescent group. The sirups of five of these six groups were influenced somewhat in quality by the fluorescent bacteria, and it is probable that the contrasts in quality are not so great as they would have been had the fluorescent bacteria been entirely eliminated; yet it still appears perfectly clear that the organisms which most seriously injure the flavor of maple sirup are not those producing the darker grades of color.

If the groups are re-arranged in the order of depreciation in score, an idea may be gained of their relative commercial values.

TABLE 14. ORDER OF AVERAGE DEPRECIATION IN SCORE

	Group	Color	Depreciation		Score
			Flavor		
1	Incubator control,	1.8	0.7		87
2	Non-fluorescent bacteria,	0.5	1.5		100
3	Failures,	3.4	0.3		108
4	Pink coccus,	2.8	1.6		171
5	Composites,	3.3	1.5		213
6	Red yeast,	4.1	1.7		215
7	Gray yeast,	3.8	1.7		234
8	Fluorescent bacteria,	4.8	1.6		242
9	<i>B. aceris</i> ,	2.7	2.0		242
10	Green molds,	4.3	2.0		281
11	Fluorescent bacteria plus spore-bearers,	4.4	2.6		307
12	Natural sour sap,	8.2	1.6		311

DISCUSSION OF LAST RUN SIRUPS

Examination of the statistical tables shows that the dark color of late run sirup is to be attributed to the action of micro-organisms, since the sirups made from last run material gathered without infection were always of a light hue. The average depreciation in color as calculated upon the first run controls was 0.8 point. At first sight it would appear that the results as applied to flavors lack uniformity. The sirups of the first season suffered no depreciation in flavor while those of the last two seasons uniformly fell off three points; but, as has been already suggested, this result is accounted for by the meteorological divergencies of the several seasons (pages 328 and 380).

INFLUENCE OF INERT EXTRANEIOUS MATERIAL

Before formulating answers to the questions propounded at the outset, attention is called to the fact that in these studies no attention has been paid to the influence upon the color and flavor of sirup of inert extraneous matter, such as colored rain water, bark, insects, caramel and the like. Everyone recognizes the importance of eliminating such material, but the following paragraph showing the influence of caramel may be worthy of record.

The commercial supply of sap from the sugar place where the inoculation experiments were carried out was concentrated

in a multiple pan evaporator in which the sirup was always drawn off from the rear pan. Of course the usual accumulation of the so-called niter (mainly malate of lime) occurred in the sirup pan. During the height of the season the capacity of the equipment was hardly sufficient for the number of buckets hung, so that in order to save time on one occasion the daily cleansing of the pan was omitted. A decided darkening was soon noted in the grade of sirup obtained and suspicion was directed towards the sirup pan. The fire was banked and the niter removed. An improvement of several points in color of the sirup immediately resulted, showing that the sugar mechanically included in the niter was being caramelized and was exercising a detrimental influence. After this the color of the sirup was carefully watched, and whenever a depreciation in color began to appear the niter was removed from the sirup pan and the former light light color of the sirup was restored.

CONCLUSIONS

Returning now to the questions these studies were inaugurated to answer, the work has shown that the depreciation in color and flavor of maple sirup which ordinarily occurs in the commercial sugar place as the season progresses is to be attributed to the action of micro-organisms. Certain groups exercise a more detrimental influence upon color than upon flavor, while with other groups the reverse is true. The influence of each group appears more or less specific and characteristic. The most common form of organisms present in maple sap, the fluorescent bacteria, injures the flavor much less than it does the color. Those organisms which most seriously affect the flavor of sirup, the non-fluorescent, spore-bearing bacteria, molds, and stringy sap organisms, do not seriously darken the color. They do, however, frequently render the sirup cloudy and so viscid that it does not clear perfectly, even if left undisturbed for months.

In addition to the depreciation due to bacteria there may occur deterioration due to physiological changes in the tree itself.

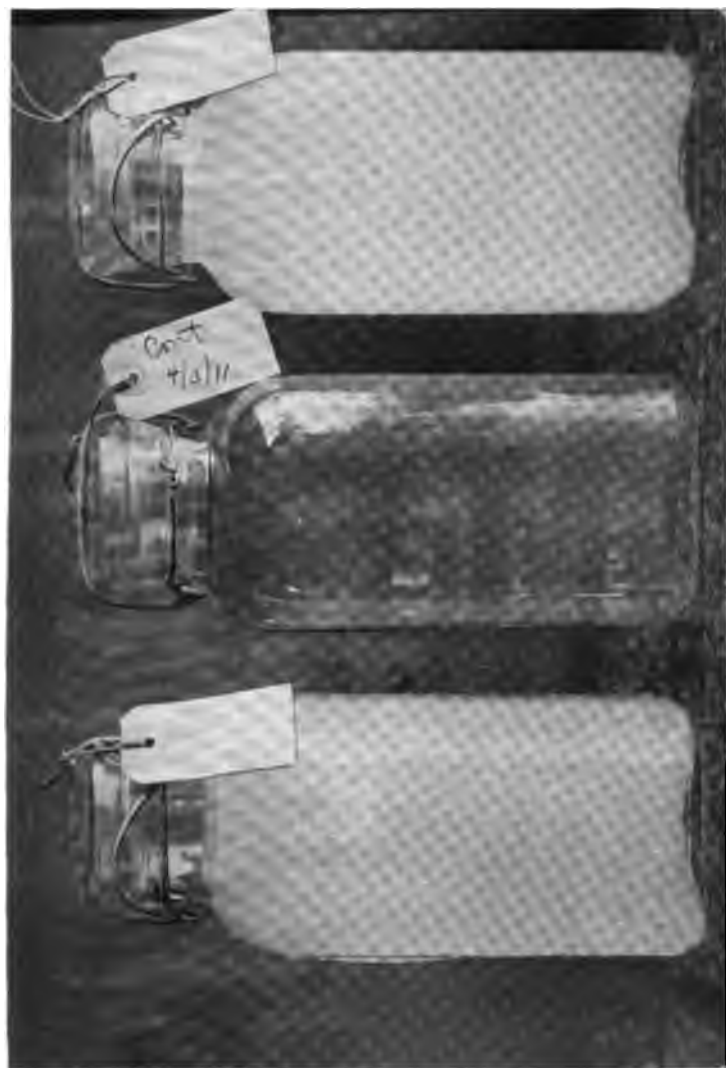


PLATE V.—A jar of normal sap compared with two jars containing an infected sap of the so-called milky type. (See pages 334-335).

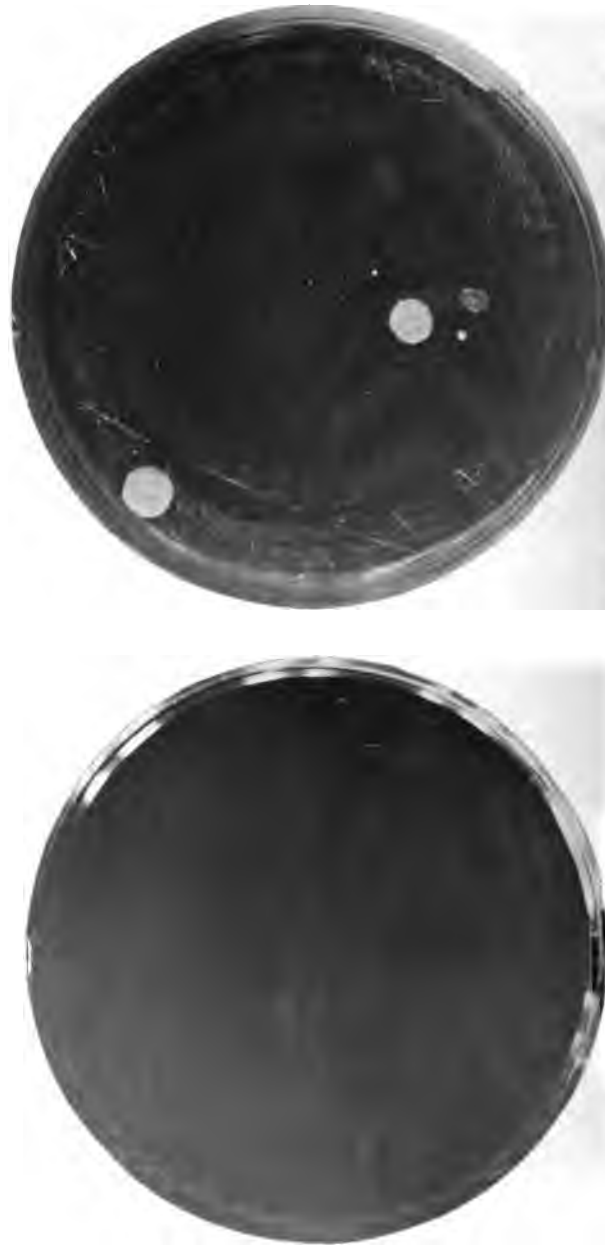


PLATE VI.—Colonies developing on nutrient agar and synthetic agar, respectively, from one-twentieth of a cubic centimeter of maple sap No. 66 received in tin buckets. (See pages 343, 373.)

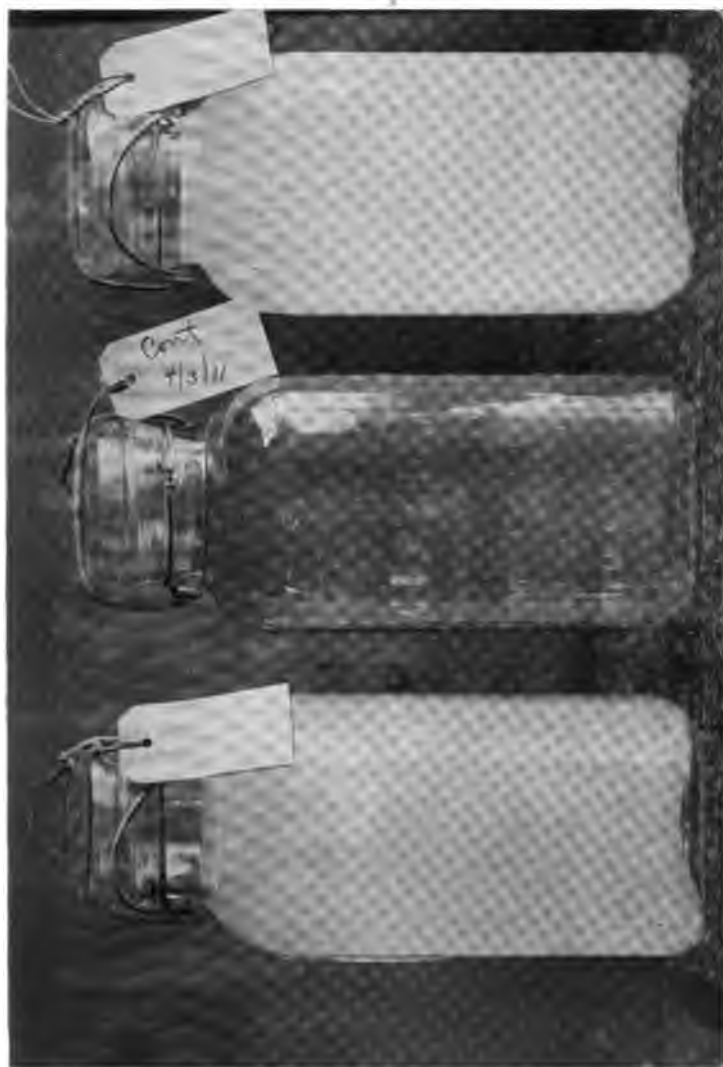


PLATE V.—A jar of normal sap compared with two jars containing an infected sap of the so-called milky type. (See pages 334-335).



PLATE VI.—Colonies developing on nutrient agar and synthetic agar, respectively, from one-twentieth of a cubic centimeter of maple sap No. 66 received in tin buckets. (See pages 343, 373.)

In certain seasons these changes which produce the "buddy" flavor may not occur in Vermont until after the sap flow ceases. In ordinary years, however, the season is interrupted by periods of growing weather, so that the vegetative activity of the tree is resumed some time before the final discontinuance of night freezes, and the influence of these physiological changes becomes manifest in the true "buddy" flavor which appears in the sirup. Formerly the opinion was commonly held that this depreciation was due to the presence of a relatively large proportion of invert sugar. An examination of the analytical data clearly demonstrates that this view is erroneous. There is a decline rather than an increase in the content of invert sugar as the season advances. The exact nature of the cause of the true buddy flavor is unknown. In this connection, attention is again directed to the statement on page 346, to the effect that frequently the so-called buddy material is not buddy in the sense in which the term is employed in this bulletin. Much sirup popularly but erroneously termed buddy possesses objectionable foreign flavors due solely to the action of micro-organisms.

REMEDIAL MEASURES

Practical remedial measures must be based upon efforts to minimize the contamination with micro-organisms and to restrict the period of their action to the shortest possible time. The lower their content and the shorter their period of growth, the better the product. As in dairying, cleanliness must be the watchword of the producer of superior goods. Clean spouts, clean and covered buckets, and clean holders are necessities. The use of metal utensils is to be preferred to the employment of wooden ones, because the latter material affords organic matter upon which organisms may develop. Moreover wooden utensils are less readily cleaned. Covered buckets are preferable to open ones, not only because they keep out rain and snow, but because they prevent the entrance of bits of falling bark, decayed wood, and other inert matter. Such material is always heavily charged

with bacteria and other organisms, so that in addition to the coloring matter carried in the refuse itself, agents are introduced which further discolor the product through their vital activities.

The practice of storing sap is one to be avoided whenever possible. Modern evaporators not only make long periods of boiling unnecessary, but they make it possible to concentrate the runs day by day as they occur. They are doubtless important factors contributing to the improved quality of evaporator sirup as compared with that produced by older methods. When storage is resorted to, the temperature of the tank should be kept as low as possible, because the lower the temperature the slower the micro-organic development. Holders should be located without rather than within the boiling house, where the heat of the pans will not influence their temperature.

The evidence obtained indicates that the sugar-maker cannot expect to produce a high quality of sirup at the close of the season in average years, because there is no known means by which the physiologically induced "buddy" flavor may be avoided. So long as the depreciation is caused solely by bacteria, cleanly methods will enable the producer to maintain a high standard of excellency in his product; but if the physiological activity of the tree begins to be manifest, the producer will find himself unable to manufacture an article of high excellency as regards flavor. The light color can be maintained indefinitely, but the "buddy" flavor is so objectionable that the market value of the sirup is insufficient to render its production profitable.

PART II

**DISCUSSION OF PHYSICAL AND CHEMICAL DATA SECURED ON
MAPLE SIRUPS OBTAINED FROM SAPS INOCULATED
WITH MICRO-ORGANISMS.**

BY C. H. JONES

The analyses of maple sirup displayed in tables 15-37 (pages 420 to 457) were made on samples secured in the prosecution of the work discussed in the preceding pages. They were obtained during three successive sugar seasons and include not only pure sirups made under the most favorable conditions possible, but, also, those representing the extremes of both natural and artificial inoculation with bacteria, yeasts and molds.

The samples were sterilized at the time of manufacture and stored in the dark in sealed half-pint "lightning" jars. All analyses were made immediately after opening the jars. Particular attention was paid to the sucrose and invert sugar contents, but, in addition, the moisture, ash, and malic acid value were secured in order to determine the effect of the treatment on the data usually employed in judging the purity of maple products. The analytical methods employed were those in ordinary use, as outlined in bulletin 134 of the Bureau of Chemistry of the United States Department of Agriculture.

It should be remembered that these samples were all pure maple sirups so far as admixture with cane or other sugars is considered. They were, however, either naturally or artificially inoculated with the types of micro-organisms normally present in maple sap. This inoculation, as will be shown, has a greater influence on color and flavor (physical characteristics) than on the chemical composition.

A total of 128 samples were examined. The analytical results are reported in groups, based mainly on the nature of the inoculating organisms employed. The sample numbers and groupings correspond to those outlined on pages 402 to 409.

Before beginning a detailed discussion, attention should be called to a few general conditions obtaining in the manufacture and analysis of the sirups, which doubtless to some extent affected the chemical data.

1. All samples were secured from the same sugar orchard.
2. They were made during three successive sugar seasons.
3. The size of the sample and the manner of its evaporation made it difficult closely to control the end boiling point and, consequently, large individual and yearly variations were observed in the concentration of the sirups, as is shown below.

TABLE 15. MOISTURE CONTENTS OF SIRUP SAMPLES

Number of samples secured	Year	Average	Maximum	Minimum	Extreme yearly variation
		%	%	%	%
26	1909	33.67	38.88	29.44	9.44
60	1910	38.01	47.60	32.46	15.14
42	1911	30.39	38.97	26.76	12.21

The average obtained in 1909 more nearly approaches the eleven-pound per gallon standard,¹ which calls for a moisture content of from 34 to 35%, than do those secured in the two following years. The 1910 samples were nearly all light weight goods, with an extreme variation of 15.14% in moisture. The average for 1911 indicates that most of the samples were considerably more concentrated than the eleven-pound standard¹ requires. A thermometer was used to determine the density during manufacture, but, unfortunately, due allowance was not made for the boiling points of different grades of sirup. These figures will be referred to later during the discussion of the ash data (pages 464 and 465).

No particular care was taken to remove the "niter" in the laboratory previous to the analysis of the 1909 samples, Nos. 1-26. It was thoroughly removed from the 102 samples of the two succeeding seasons by sedimentation during a period of seven months.

¹ Vt. Sta. Bul. 26 (1891); Rpt. 18, p. 334 (1905); U. S. Dept. Agr., Bu. Chem., Bul. 134, pp. 74-75 (1910).

EXPLANATION OF PHYSICAL AND CHEMICAL DATA SHOWN IN
TABLES 16 TO 34

The chemical analysis of each sample was preceded by a careful physical examination, for the details of which see pages 345 to 349. The color was determined after the standard of Bryan¹ which comprises twenty grades. (See page 349). The first grade is never obtained in practical manufacture. As commercially rated for average crops, any grade below 8 may be considered No. 1, from 8 to 11 inclusive No. 2, and from 12 to 15 inclusive No. 3.

The sirups were grouped in 6 classes as regards flavor. No. 1 corresponding to prime, 2 good, 3 medium, 4 poor, 5 buddy, and 6 buddy and rank. A certain few sirups grading good and medium, were designated 2¹ and 2², and similarly a few, falling between medium and poor, were rated 3¹. A flavor of 5 or 6 would immediately condemn the sample for commercial purposes.

The scoring system adopted for these sirups is based on the flavor and color as explained on pages 346 to 349.

The column headed "undetermined" is obtained by subtracting the sum of the moisture, sucrose, invert sugar, ash and malic acid value from 100. It is, of course, affected by all the errors in the five determinations mentioned, and includes proteids, tannin, organic acids and other non-sugars.

GROUP I. *Controls.* As the word "control" indicates, these samples were prepared from sap selected to serve as checks on experimental procedure. The first two lots, Nos. 6 and 20, were not boiled fresh, but were held in the cold for about 3 days during the incubation period. All the other saps in this group were strictly fresh when boiled.

The resulting sirups were of fine flavor and light in color. No. 49 is credited with the highest score possible, 975, while 5 more of the 11 lots are hardly inferior to No. 49. They would all be classed as of the highest grade.

¹U. S. Dept. Agr., Bu. Chem., Bul. 134, p. 15 (1910).

TABLE 16. MAPLE SIRUP. CONTROLS

Sample number	Color	Flavor	Score	Moisture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
6	6	1	875	33.99	62.98	0.64	0.62	0.27	0.35	0.61	1.16
20	6	1	875	33.54	63.38	1.05	0.83	0.25	0.58	1.04	0.16
27	4	2	875	34.46	63.04	0.20	0.49	0.34	0.15	0.48	1.33
41	4	1	925	39.78	58.46	0.62	0.46	0.22	0.24	0.53	0.15
49	2	1	975	38.39	59.46	0.26	0.50	0.24	0.26	0.51	0.88
58	3	1	950	36.30	61.80	0.28	0.47	0.28	0.19	0.53	0.62
68	4	1	925	37.33	60.73	0.32	0.42	0.28	0.14	0.51	0.69
89	3	2	900	29.96	67.11	0.24	0.43	0.22	0.21	0.73	1.53
97	3	1	950	30.36	66.88	0.13	0.47	0.30	0.17	0.51	1.65
105	3	2	900	30.53	66.85	0.17	0.55	0.38	0.17	0.42	1.48
113	4	2	875	29.99	67.89	0.43	0.53	0.35	0.18	0.51	0.65
Average,	3.8	1.4	911	34.06	63.51	0.39	0.52	0.28	0.24	0.57	0.95
Max.,	6	2	975	39.78	67.89	1.05	0.83	0.38	0.58	1.04	1.65
Min.,	2	1	875	29.96	58.46	0.13	0.42	0.22	0.14	0.42	0.15

 MAPLE SIRUP. CONTROLS
 Calculated to a moisture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
6	95.41	0.97	0.94	0.41	0.53	36	94	0.92	1.76	3-24-09
20	95.37	1.58	1.25	0.38	0.87	45	129	1.56	0.24	4- 1-09
27	96.19	0.30	0.75	0.53	0.22	58	71	0.73	2.03	3- 7-10
41	97.08	1.03	0.77	0.37	0.40	59	85	0.88	0.24	3-14-10
49	96.51	0.42	0.81	0.39	0.42	52	85	0.83	1.43	3-20-10
58	97.01	0.43	0.73	0.43	0.30	58	113	0.83	1.00	3-21-10
68	96.90	0.51	0.68	0.45	0.23	54	56	0.81	1.10	3-22-10
89	95.81	0.34	0.61	0.32	0.29	44	53	1.01	2.23	3-22-11
97	96.04	0.19	0.68	0.43	0.25	56	49	0.73	2.36	3-26-11
105	96.23	0.24	0.79	0.54	0.25	58	48	0.61	2.13	3-27-11
113	96.37	0.61	0.75	0.50	0.25	62	58	0.73	0.94	3-30-11
Av'ge,	96.32	0.60	0.77	0.41	0.36	51	77	0.86	1.45	
Max.,	97.08	1.58	1.25	0.54	0.87	62	129	1.56	2.36	
Min.,	95.37	0.19	0.61	0.32	0.22	36	48	0.61	0.24	

The average water content for the group is 34.06%. This figure is about normal, yet individual sirups vary from 39.78 to 29.96%. The sucrose shows the usual variations depending on the moisture content, ranging from 58.46 to 67.89, and averaging 63.51%. When calculated to a dry matter basis these large variations are eliminated and the average sucrose content becomes 96.32%. The invert sugar varies from 0.13 to 1.05, averaging 0.39%. Investigation has shown that there are but very small amounts of invert sugar in the sap of the maple as it comes from the tree, and, consequently, if quickly and properly concentrated, the resulting sirup should carry only a small amount. When the invert sugar in maple sirup calculated to a moisture free basis is less than 0.60%, it should not be attributed to excessive micro-organic infection. No. 20 was obtained about the middle of the season of 1909 from sap held 3 days in the cold; and its invert sugar percentage, 1.05, would indicate that the sucrose had suffered a slight decomposition.

The minimum ash and malic acid value figures established by the writer for pure Vermont maple sirup of standard weight and density, together with similar data obtained by Bryan for Vermont as well as for the United States², are shown in the following table:

TABLE 17. MINIMUM ASH AND MALIC ACID VALUES FOR PURE MAPLE SIRUP
Calculated to a moisture-free basis

	Jones (¹) Vermont samples	Bryan (²) Vermont samples	Bryan (²) United States samples
Total ash,	0.77%	0.77%	0.68%
Insoluble ash,	0.23%	0.23%	0.23%
Malic acid value,	0.61%	0.58%	0.31%

The agreement on the Vermont samples is very close. The Jones standard was secured on samples made in 1904 and the Bryan results on those obtained in 1909. In both cases they are based on about 50 samples representing all grades of pure

¹ Vt. Sta. Rpt. 18, p. 334 (1905).

² U. S. Dept. Agr., Bu. Chem., Bul. 134, pp. 74-75 (1910).

sirup. The United States minimum is based on 395 samples, representing all the important maple sugar producing sections. Attention is called to the fact that the minimum for insoluble ash for the entire United States is identical with the figure twice obtained by different investigators on Vermont samples.

The ash and malic acid value data of the sirups in this and subsequent groups will be discussed primarily with a view of comparing the data with the standards just enumerated. It should be remembered that many of the samples discussed in the following groups are exceptional as to inoculation and manufacture. Such divergencies from the normal as were found will be noted and reasons assigned for the deficiencies.

The average total and insoluble ash contents of the group on a moisture free basis are 0.77 and 0.36% respectively, with variations for total ash from 0.61 to 1.25 and for insoluble ash from 0.22 to 0.87%. While the average of these 11 sirups is normal as regards standards, yet in six cases the total ash is below 0.77% (the Vermont standard) and in one case below the United States minimum. The insoluble ash runs 0.01% low in one instance, but in all others equals or exceeds the 0.23% figure.

The malic acid value meets the standard in every instance, the average figure obtained being 0.86%, with extremes of 1.56 and 0.61%.

Attention is here called to the fact that, excepting Nos. 27, 58 and 68, the samples showing a low total ash had a relatively small water content, and that in all cases the "niter" had been thoroughly removed by a full seven months' sedimentation. The deficiencies occurring during 1910 and 1911, if considered in connection with color, flavor, and the remaining ash and malic acid data, would not embarrass the analyst familiar with maple products.

The undetermined column shows variations from 0.24 to 2.36, averaging 1.45%, which is about the usual amount found in the ordinary run of good grade maple sirups.

GROUP 2. *Incubator controls.* The saps from which these sirups were made were kept during the incubation period, generally not over 3 days, before being concentrated. They were in many cases probably slightly contaminated from natural sources and should, therefore, be considered only as of ordinary quality. Sample 43 remained clear for 2 days, but showed a milky bacterial growth the third day before boiling. No. 65 likewise soured early and made a sirup of poor quality. All the samples graded well as to color and in only two cases was the flavor considered medium or poor.

TABLE 18. MAPLE SIRUP. INCUBATOR CONTROLS

Sample number	Color	Flavor	Score	Molsture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
1	7	1	850	38.52	59.54	0.66	0.61	0.24	0.37	0.65	0.02
34	6	2 ¹	800	36.06	60.97	0.27	0.90	0.38	0.52	0.91	0.89
38	5	2 ¹	825	38.37	58.45	0.30	0.71	0.34	0.37	0.62	1.55
40	9	2	750	34.89	61.89	0.42	0.63	0.25	0.38	0.59	1.58
43	7	2	800	40.03	56.39	1.58	0.53	0.25	0.28	0.53	0.94
45	4	1	925	42.19	55.66	0.30	0.52	0.24	0.28	0.60	0.73
56	5	2	850	37.92	59.61	0.84	0.56	0.34	0.22	0.46	0.61
57	2	1	975	40.65	57.26	0.36	0.48	0.25	0.23	0.53	0.72
65	6	4	625	42.03	53.27	2.04	0.60	0.25	0.35	0.63	1.43
96	5	2	850	27.81	68.82	0.32	0.51	0.33	0.18	0.42	2.12
104	4	2	875	29.46	68.42	0.29	0.49	0.33	0.16	0.41	0.93
112	5	2	850	31.34	67.01	0.76	0.49	0.35	0.14	0.31	0.09
120	5	3	775	38.97	58.06	0.35	0.44	0.28	0.16	0.44	1.74
Average,	5.4	2.0	827	36.78	60.41	0.65	0.57	0.29	0.28	0.55	1.04
Max.,	9	1	975	42.19	68.82	2.04	0.90	0.38	0.52	0.91	2.12
Min.,	2	3	625	27.81	53.27	0.27	0.44	0.24	0.14	0.31	0.02

MAPLE SIRUP. INCUBATOR CONTROLS
Calculated to a molsture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
1	96.84	1.07	0.99	0.39	0.60	55	120	1.06	0.04	3-24-09
34	95.36	0.42	1.41	0.59	0.82	69	153	1.42	1.39	3- 7-10
38	94.80	0.48	1.15	0.55	0.60	74	119	1.00	2.57	"
40	95.05	0.64	0.96	0.38	0.58	62	107	0.91	2.44	"
43	94.19	2.64	0.88	0.41	0.47	58	88	0.88	1.41	3-14-10
45	96.28	0.51	0.89	0.41	0.48	60	96	1.04	1.28	"
56	96.02	1.35	0.90	0.54	0.36	58	95	0.73	1.00	3-20-10
57	96.47	0.60	0.81	0.52	0.39	61	81	0.90	1.22	"
65	91.89	3.52	1.03	0.43	0.60	60	122	1.09	2.47	3-21-10
96	95.33	0.44	0.71	0.46	0.25	55	49	0.65	2.87	3-22-11
104	97.00	0.41	0.69	0.47	0.22	62	42	0.60	1.30	3-26-11
112	97.60	1.11	0.71	0.50	0.21	59	47	0.44	0.14	3-27-11
120	95.12	0.57	0.71	0.45	0.26	66	75	0.72	2.88	3-30-11
Average,	95.55	1.04	0.90	0.46	0.44	61	92	0.87	1.64	
Max.,	97.60	3.52	1.41	0.59	0.82	74	153	1.42	2.87	
Min.,	91.89	0.41	0.69	0.38	0.21	55	42	0.44	0.04	

The moisture content in these thirteen samples varies from 27.81 to 42.19 with an average of 36.78%.

The sucrose ranges from 53.27 to 68.82 and averages 60.41%. No. 65, which contains the lowest sucrose figure, is in consequence high in both water and invert sugar.

The invert sugar averages 0.65% with a maximum of 2.04 and a minimum of 0.27%. None of the samples, save Nos. 43 and 65, show marked evidences of souring previous to boiling. No. 1 was purposely evaporated at a slow rate, about 6 hours, or four times the usual interval, being taken. Its low invert sugar content, 0.66%, together with its satisfactory flavor and color, indicate that the time taken in boiling this fairly pure sap produced no marked inversion effect on the sucrose.

Four of these samples, Nos. 96, 104, 112 and 120, when calculated to a moisture free basis, show a deficiency of total ash, two of which, Nos. 104 and 112, are just under the limit for insoluble ash, while one, No. 112, is low in malic acid value. In three of these four cases the concentration of the sirup was carried too far, the moisture content ranging from 27.81 to 31.34%. The malic acid value figure, 0.44%, is the lowest ever observed by the writer on pure Vermont goods.

GROUP 3. *Inoculated with non-fluorescent bacteria.* These organisms are common in nature. When they occur in the sap and are allowed to develop, they injure the flavor more than they do the color of the resulting sirup. Two of the four samples were rated medium as to flavor, and two, good. The color of all four was exceptionally light, easily being classed No. 1 as commercially graded.

TABLE 19. MAPLE SIRUP. INOCULATED WITH NON-FLUORESCENT BACTERIA

Sample number	Color	Flavor	Score	Moisture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
9	5	2	850	33.26	63.81	0.52	0.57	0.26	0.31	0.47	1.37
10	6	3	750	32.21	64.98	0.52	0.78	0.27	0.51	0.60	0.91
12	6	3	750	36.35	60.92	1.42	0.76	0.27	0.49	0.73	—18
55	5	2	850	36.97	59.73	1.50	0.63	0.26	0.37	0.48	0.69
Average,	5.5	2.5	800	34.70	62.36	0.99	0.69	0.27	0.42	0.57	0.69
Max.,	6	3	850	36.97	64.98	1.50	0.78	0.27	0.51	0.73	1.37
Min.,	5	2	750	32.21	59.73	0.52	0.57	0.26	0.31	0.47	—18

MAPLE SIRUP. INOCULATED WITH NON-FLUORESCENT BACTERIA
Calculated to a moisture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
9	95.61	0.78	0.85	0.39	0.46	51	117	0.70	2.06	3-27-09
10	95.86	0.77	1.15	0.40	0.75	35	145	0.88	1.34	"
12	95.71	2.23	1.19	0.42	0.77	41	145	1.14	—27	"
55	94.76	2.38	1.00	0.40	0.60	57	123	0.75	1.11	3-20-10
Average,	95.50	1.52	1.06	0.42	0.64	46	132	0.87	1.05	
Max.,	95.86	2.38	1.19	0.42	0.77	57	145	1.14	2.06	
Min.,	94.76	0.77	0.85	0.39	0.46	35	117	0.70	—27	

The moisture content of these samples was quite uniform, a variation of less than 5% being found. Its average was 34.70%.

The sucrose varied from 59.73 to 64.98, averaging 62.36%.

The invert sugar, while averaging higher than in the previously mentioned controls, did not show such extremes. The average of 0.99% as analyzed, equivalent to 1.52% on a dry basis, is clearly indicative of the fact that the organisms used were not active inverters of sucrose. The records show that the sap from which sirup 55 was made had a bacterial count of nearly 3,000,000. While apparently inactive as regards inversion they did, however, affect the flavor of the product, causing it to fall off 1.5 points from the control.

The ash and malic acid value data in all cases exceed the usual standard. It should be noted, however, that the first three samples, Nos. 9, 10 and 12, were from the 1909 crop, and, as has been mentioned, no particular care was taken to remove all niter as was the case with No. 55.

GROUP 4. *Inoculated with pink cocci.* The presence of these organisms in maple sap is decidedly detrimental to the production of a first class sirup. They seriously affect the flavor but have no marked influence on the color.

TABLE 20. MAPLE SIRUP. INOCULATED WITH PINK COCCI

Sample number	Color	Flavor	Score	Moisture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
46	6	2	825	38.42	58.55	0.65	0.63	0.27	0.36	0.60	1.15
47	6	3	750	40.64	52.72	4.69	0.60	0.27	0.33	0.52	0.83
50	6	2 ¹	800	40.03	56.17	1.32	0.50	0.23	0.27	0.50	1.48
51	4	2	875	37.65	60.67	0.41	0.51	0.31	0.20	0.49	0.27
107	6	4	600	27.90	68.15	0.50	0.51	0.36	0.15	0.42	2.52
54	7	2 ¹	750	38.30	58.07	1.67	0.51	0.27	0.24	0.44	1.01
Average,	5.7	2.6	775	37.15	59.05	1.54	0.54	0.28	0.26	0.50	1.22
Max.,	7	4	875	40.64	68.15	4.69	0.63	0.36	0.36	0.60	2.52
Min.,	4	2	600	27.90	52.72	0.41	0.50	0.23	0.15	0.42	0.27

MAPLE SIRUP. INOCULATED WITH PINK COCCI

Calculated to a moisture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
46	95.07	1.05	1.02	0.44	0.58	162	113	0.97	1.89	3-14-10
47	88.81	7.90	1.01	0.46	0.55	64	107	0.88	1.40	"
50	93.83	2.20	0.83	0.38	0.45	62	95	0.83	2.31	3-20-10
51	97.30	0.65	0.82	0.50	0.32	63	73	0.79	0.44	"
107	94.52	0.69	0.71	0.50	0.21	57	34	0.58	3.50	3-27-11
54	94.11	2.71	0.82	0.43	0.39	56	75	0.71	1.65	3-20-10
Average,	93.94	2.45	0.86	0.45	0.41	61	83	0.79	1.96	
Max.,	97.30	7.90	1.02	0.50	0.58	64	113	0.97	3.50	
Min.,	88.81	0.65	0.71	0.38	0.21	56	34	0.58	0.44	

The moisture content of the six sirups averaged 37.15 with extremes of 40.64 to 27.90%. The minimum amount is found in No. 107, the only 1911 sample in this series.

The sucrose averages 59.05 and the extremes are 52.72 and 68.15%. The sample, No. 47, with the highest moisture content carries the lowest sucrose percentage. The relatively large amount of invert sugar present is also a contributing factor.

The invert sugar shows a surprising variation of from 0.41 to 4.69 with an average of 1.54%. This maximum figure, in No. 47, when calculated to the moisture free basis is equivalent to 7.90%. This result may be attributed to the action on the sucrose of a certain strain of pink coccus. Other strains did not give as positive evidences of sucrose inversion.

No. 107, as compared with standard, is slightly deficient in total and insoluble ash and in malic acid value.

GROUP 5. *Failures.* The saps from which the sirups thus characterized were made, were variously inoculated, but the introduced organisms could not be recovered at the close of the incubation period. The natural infection may have suppressed their development or the inoculating organisms may have been killed by those normally present. Whatever the infection, it had no marked influence upon the results in the invert sugar column.

The color averaged a little poorer in these samples than in those previously mentioned under the head "incubator control," while flavor showed a slight gain.

TABLE 21. MAPLE SIRUP. FAILURES

Sample number	Color	Flavor	Score	Moisture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
31	6	2	825	38.21	59.70	0.19	0.70	0.34	0.36	0.34	0.86
32	6	2	825	37.37	60.07	0.29	0.71	0.25	0.46	0.65	0.91
33	7	2	800	35.96	61.23	0.15	0.76	0.34	0.42	0.64	1.26
36	9	2 ¹	725	37.52	60.08	0.38	0.65	0.27	0.38	0.45	0.92
37	11	2 ¹	675	34.43	62.87	0.41	0.73	0.24	0.49	0.65	0.91
39	7	2	800	36.34	61.23	0.17	0.71	0.22	0.49	0.62	0.93
106	7	3	725	30.48	67.64	0.46	0.48	0.33	0.15	0.41	0.53
108	4	3	800	29.64	67.10	0.63	0.46	0.32	0.14	0.35	1.82
Average,	7.0	2.3	772	34.99	62.48	0.33	0.65	0.29	0.36	0.52	1.03
Max.,	11	3	825	38.21	67.64	0.63	0.76	0.34	0.49	0.65	1.82
Min.,	6	2	675	29.64	59.70	0.15	0.46	0.22	0.14	0.34	0.53

 MAPLE SIRUP. FAILURES
 Calculated to a moisture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
31	96.62	0.30	1.14	0.55	0.59	62	133	0.55	1.39	3- 7-10
32	95.91	0.46	1.13	0.39	0.74	54	102	1.03	1.47	" "
33	95.61	0.23	1.18	0.52	0.66	62	151	0.99	1.99	" "
36	96.16	0.61	1.06	0.44	0.62	57	105	0.73	1.44	" "
37	95.88	0.64	1.11	0.36	0.75	51	79	0.99	1.38	" "
39	96.18	0.26	1.12	0.35	0.77	67	120	0.97	1.47	" "
106	97.30	0.66	0.69	0.47	0.22	58	56	0.59	0.76	3-27-11
108	95.37	0.90	0.65	0.45	0.20	58	37	0.49	2.59	" "
Average,	96.13	0.51	1.00	0.45	0.55	59	98	0.80	1.56	
Max.,	97.30	0.90	1.18	0.55	0.77	67	151	1.03	2.59	
Min.,	95.37	0.23	0.65	0.35	0.20	51	37	0.49	0.76	

The moisture in the sirups of this group varies from 29.64 to 38.21, and averages 34.99%.

The sucrose averages 62.48%, equivalent, on a moisture free basis, to 96.13%.

The invert sugar percentages were low, the average on a moisture free basis being 0.51%, the highest, 0.90, the lowest 0.23%. This checks closely with the results shown in tables 16 and 18, with which the data secured with the samples of this group are comparable.

The total and insoluble ash contents are low of standard in two of the eight samples and the malic acid value is deficient in three samples.

GROUP 6. *Inoculated with red yeasts.* These organisms are quite common, particularly toward the close of the season. The evaporating sap and sirup containing them give off an offensive yeasty odor. They seriously impair the flavor and in many instances cause the color to grade several shades darker than it otherwise would; and they also materially increase the invert sugar content because of their action on the sucrose.

TABLE 22. MAPLE SIRUP. INOCULATED WITH RED YEASTS

Sample number	Color	Flavor	Score	Molsture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
14	10	2	725	33.17	63.69	2.01	0.87	0.31	0.56	0.59	-0.33
62	9	4	550	40.18	53.40	4.37	0.51	0.22	0.29	0.49	1.05
15	8	2	750	38.88	57.00	1.82	0.77	0.26	0.51	0.92	0.61
114	5	3	775	30.69	66.75	0.70	0.49	0.34	0.15	0.39	0.98
18	10	2	725	30.17	64.00	2.18	0.72	0.27	0.45	0.72	2.21
35	12	2 ¹	650	32.66	64.06	0.77	0.64	0.25	0.39	0.56	1.31
42	5	2 ²	800	41.31	54.74	1.26	0.69	0.36	0.33	0.72	1.28
59	7	3	725	38.97	57.82	1.24	0.59	0.30	0.29	0.54	0.84
60	6	3	750	38.16	59.02	1.09	0.52	0.33	0.19	0.67	0.54
61	9	3	675	35.92	61.39	1.13	0.54	0.30	0.24	0.47	0.55
99	7	4	600	28.11	68.17	1.47	0.54	0.32	0.22	0.45	1.26
63	8	3	700	37.23	55.90	4.79	0.55	0.27	0.28	0.50	1.03
64	8	3	700	35.88	58.76	3.76	0.51	0.27	0.24	0.46	0.63
Average,	8	2.8	703	35.48	60.36	2.05	0.62	0.30	0.32	0.61	0.88
Max.,	12	4	800	41.31	68.17	4.79	0.87	0.36	0.56	0.92	2.21
Min.,	5	2	550	28.11	53.40	0.70	0.49	0.22	0.15	0.39	-0.33

MAPLE SIRUP. INOCULATED WITH RED YEAST
Calculated to a moisture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
14	95.30	3.01	1.30	0.46	0.84	33	144	0.88	-49	4-1-09
62	89.27	7.30	0.86	0.37	0.49	51	103	0.83	1.74	3-21-10
15	93.26	2.98	1.26	0.43	0.83	69	164	1.50	1.00	4-1-09
114	96.31	1.01	0.71	0.49	0.22	61	52	0.56	1.41	3-30-11
18	91.65	3.12	1.03	0.39	0.64	49	112	1.03	3.17	4-1-09
35	95.13	1.15	0.95	0.37	0.58	67	114	0.84	1.93	3-7-10
42	93.27	2.14	1.18	0.61	0.57	58	122	1.23	2.18	3-14-10
59	94.74	2.03	0.97	0.49	0.48	65	99	0.88	1.38	3-21-10
60	95.44	1.76	0.85	0.53	0.32	58	91	1.08	0.87	"
61	95.80	1.77	0.84	0.46	0.38	64	81	0.73	0.86	"
99	94.82	2.05	0.75	0.44	0.31	57	63	0.67	1.71	3-26-11
63	89.06	7.63	0.88	0.43	0.45	63	91	0.80	1.63	3-21-10
64	91.64	5.86	0.79	0.42	0.37	54	82	0.72	0.99	"
Average,	93.54	3.18	0.96	0.47	0.49	58	101	0.91	1.41	
Max.,	96.31	7.63	1.30	0.61	0.84	69	164	1.50	3.17	
Min.,	89.06	1.01	0.71	0.37	0.22	33	52	0.56	-49	

The moisture shows the usual variations, averaging 35.48%.

The sucrose averages 60.36, with a maximum of 68.17 and a minimum of 53.40%.

The invert sugar averages 2.05 and extremes range from 0.70 to 4.79%. This maximum is equivalent to 7.63% on a moisture free basis. The count secured on the plated sap previous to boiling seems to bear no direct relation to the amount of invert sugar. The count includes both bacterial and yeast colonies, however, so that the figures do not express the relative infection with yeasts. The variations in the invert sugar content may be assigned partly to differences in the individual strains employed and partly to the different degrees of infection secured. (See table 9, pages 392 to 395, Nos. 42, 63 and 64).

The total ash in Nos. 114 and 99 is below standard and the insoluble ash in No. 114 is also 0.01% low. The malic acid value is likewise a few points shy in No. 114. Both these samples were quite concentrated, their water contents being 30.69 and 28.11% respectively.

GROUP 7. *Inoculated with gray yeasts.* These organisms are closely associated with the red yeasts previously mentioned and, like them, are quite commonly found late in the sugar season. Their action is detrimental to a good flavored sirup, four out of the eight samples being graded 4 in flavor, corresponding to poor. In two cases the color was considerably darkened, being classed 10 and 11, corresponding to a No. 2 commercial grade. The invert sugar was increased in every case and a maximum percentage of 19.15% was found in No. 109.

TABLE 23. MAPLE SIRUP. INOCULATED WITH GRAY YEASTS

Sample number	Color	Flavor	Score	Molsture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
13	7	2	800	36.05	59.69	1.62	0.79	0.30	0.49	0.92	0.93
28	11	4	500	35.93	53.07	7.79	0.79	0.28	0.51	0.67	1.75
109	10	4	525	32.44	45.49	19.15	0.60	0.33	0.27	0.61	1.71
48	6	2 ^a	775	38.49	57.75	1.44	0.63	0.35	0.28	0.51	1.18
52	5	2	850	38.37	59.68	0.75	0.56	0.30	0.26	0.51	0.13
53	6	3	750	41.50	53.90	2.32	0.49	0.32	0.17	0.60	1.19
110	6	4	625	30.94	67.05	1.20	0.46	0.30	0.16	0.46	—11
115	7	4	600	31.04	65.61	1.05	0.50	0.35	0.15	0.43	1.37
Average, 7.3	3.2		678	35.60	57.78	4.42	0.60	0.32	0.28	0.59	1.01
Max., 11	4		850	41.50	67.05	19.15	0.79	0.35	0.51	0.92	1.75
Min., 5	2		500	30.94	45.49	0.75	0.46	0.28	0.15	0.43	—11

MAPLE SIRUP. INOCULATED WITH GRAY YEAST
Calculated to a molsture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
13	93.34	2.53	1.24	0.47	0.77	56	141	1.44	1.45	4-10-09
28	82.83	12.15	1.23	0.44	0.79	62	151	1.04	2.75	3- 7-10
109	67.33	28.35	0.88	0.49	0.39	50	102	0.90	2.54	3-27-11
48	93.89	2.35	1.03	0.58	0.45	60	102	0.83	1.90	3-14-10
52	96.84	1.21	0.90	0.49	0.41	63	85	0.82	0.27	3-20-10
53	92.13	3.96	0.84	0.54	0.30	62	71	1.03	2.04	"
110	97.09	1.74	0.67	0.44	0.23	58	52	0.65	—15	3-27-11
115	95.14	1.52	0.72	0.51	0.21	61	53	0.62	2.00	3-30-11
Average, 89.72	6.86	0.94	0.50	0.44	0.44	59	95	0.92	1.56	
Max., 97.09	28.35	1.24	0.58	0.79	63	151	1.44	2.75		
Min., 67.33	1.21	0.67	0.44	0.21	50	52	0.62	—15		

The moisture content varied from 30.94 to 41.50 and averaged 35.60%.

The sucrose averaged 57.78% with extremes of 45.49 and 67.05%. The low figure which was obtained on No. 109 is due mainly to the high invert sugar content of 19.15%, equivalent on the moisture free material to 28.35%. This was the largest invert sugar percentage obtained with any of the samples examined. Reference to the field notes shows that the inoculating organism multiplied rapidly and was an acid producer, a condition which doubtless served to hasten the sucrose inversion.

The total ash on the moisture free basis shows a deficiency in two cases, Nos. 110 and 115. The insoluble ash is also low in No. 115. The malic acid value meets the standard in every case.

GROUP 8. *Inoculated with fluorescent bacteria.* These organisms occur more commonly in maple sap than do any of the others used in this work. They grow well at low temperatures and hence should be guarded against early in the season. They impair the flavor somewhat although not as seriously as several other groups. Nine of the 22 samples reported were graded as No. 2 in flavor, indicative of a good sirup, six as No. 3, a good medium sirup, while seven were classed as No. 4, corresponding to poor. The color was seriously injured by this fluorescent group. They cause but little if any inversion of the sucrose and never produce the objectionable yeasty taste so characteristic of many contaminated sirups.

TABLE 24. MAPLE SIRUP. INOCULATED WITH FLUORESCENT BACTERIA

Sample number	Color	Flavor	Score	Moisture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
2	14	4	425	31.01	66.77	1.07	0.71	0.30	0.41	0.54	—10
102	7	4	600	28.81	68.11	0.81	0.58	0.41	0.17	0.36	1.31
3	11	2	700	31.15	66.60	1.44	0.81	0.32	0.49	0.59	—59
103	7	4	600	28.75	67.97	0.96	0.52	0.32	0.20	0.43	1.37
4	9	2	750	30.69	66.91	1.08	0.71	0.33	0.38	0.65	—04
5	11	2	700	33.55	64.56	0.96	0.59	0.27	0.32	0.44	—10
7	10	2	725	32.72	64.69	1.10	0.64	0.20	0.44	0.59	0.26
8	10	2	725	33.96	64.15	0.76	0.58	0.29	0.29	0.50	0.05
101	8	3	700	28.36	69.10	0.67	0.51	0.32	0.19	0.38	0.98
29	8	2	750	37.31	59.50	0.24	0.67	0.24	0.43	0.54	1.74
30	8	2	775	32.91	64.90	0.60	0.71	0.30	0.41	0.63	0.25
44	9	3	675	38.72	57.01	0.86	0.64	0.25	0.39	0.70	2.07
100	7	3	725	27.76	69.59	0.87	0.57	0.39	0.18	0.40	1.01
69	9	3	675	37.17	58.91	1.00	0.76	0.24	0.52	0.79	1.37
70	11	4	500	36.72	59.15	1.56	0.80	0.34	0.46	0.70	1.07
71	14	4	425	37.87	58.20	0.36	*...*	*...*	*...*	0.66	....
72	13	4	450	36.57	60.30	0.28	0.66	0.19	0.47	0.66	1.53
73	6	2	825	33.31	65.00	0.45	0.55	0.32	0.23	0.48	0.21
91	6	3	750	26.76	69.40	0.29	0.53	0.32	0.21	0.66	2.36
92	7	3	725	28.46	67.96	0.37	0.58	0.37	0.21	0.53	2.10
93	6	2	825	28.06	68.65	0.31	0.60	0.41	0.19	0.39	1.99
94	7	4	600	28.51	67.69	0.37	0.51	0.30	0.21	0.46	2.46
Average, 9		2.9	665	32.23	64.79	0.74	0.63	0.31	0.32	0.55	1.06
Max., 14		4	825	38.72	69.59	1.56	0.81	0.41	0.52	0.79	2.46
Min., 6		2	425	26.76	57.01	0.24	0.51	0.19	0.17	0.36	—59

MAPLE SIRUP. INOCULATED WITH FLUORESCENT BACTERIA
Calculated to a moisture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
2	96.79	1.55	1.03	0.44	0.59	49	113	0.78	-0.15	3-24-09
102	95.67	1.14	0.82	0.58	0.24	64	58	0.50	1.87	3-26-11
3	96.73	2.09	1.18	0.47	0.71	52	113	0.86	-0.86	3-24-09
103	95.38	1.35	0.73	0.45	0.28	56	65	0.60	1.94	3-26-11
4	96.54	1.56	1.02	0.48	0.54	52	110	0.93	-0.05	3-24-09
5	97.16	1.44	0.89	0.41	0.48	48	99	0.67	-0.16	3-24-09
7	96.16	1.64	0.95	0.30	0.65	54	104	0.88	0.37	3-27-09
8	97.14	1.15	0.88	0.44	0.44	42	82	0.75	0.08	"
101	96.45	0.94	0.71	0.44	0.27	60	56	0.53	1.37	3-26-11
29	94.91	0.38	1.07	0.39	0.68	61	131	0.87	2.77	3-7-10
30	93.75	0.89	1.06	0.45	0.61	63	122	0.93	3.37	"
44	93.03	1.40	1.06	0.41	0.65	61	122	1.15	3.36	3-14-10
100	96.21	0.93	0.79	0.54	0.25	61	50	0.55	1.52	3-26-11
69	93.87	1.59	1.21	0.38	0.83	69	153	1.26	2.07	3-22-10
70	93.47	2.46	1.26	0.53	0.73	62	176	1.10	1.71	"
71	93.67	0.58	*...*	*...*	*...*	*..	*..	1.06	....	"
72	95.07	0.44	1.03	0.29	0.74	64	150	1.03	2.43	"
73	97.47	0.68	0.83	0.48	0.35	70	66	0.71	0.31	"
91	94.76	0.40	0.72	0.44	0.28	58	58	0.90	3.22	3-22-11
92	95.00	0.52	0.81	0.51	0.30	57	76	0.74	2.93	"
93	95.43	0.43	0.83	0.56	0.27	70	54	0.54	2.77	"
94	94.68	0.52	0.72	0.41	0.31	57	45	0.64	3.44	"
Average,	95.42	1.09	0.93	0.46	0.47	59	95	0.82	1.74	
Max.,	97.47	2.46	1.26	0.58	0.83	70	176	1.26	3.44	
Min.,	93.03	0.38	0.71	0.29	0.24	48	45	0.50	-0.86	

*Not determined through inadvertence.

The moisture ranged from 26.75 to 38.72, averaging 32.23%.

The sucrose variations, inasmuch as the invert sugar is low, follow the water content quite closely. The minimum found was 57.01, the maximum 69.59 and the average 64.79%.

The invert sugar variations of from 0.24 to 1.56, with the average of 0.74%, indicate quite conclusively that the inoculating organisms were not invert sugar formers.

The total ash as recorded in the moisture free basis table is below standard in Nos. 103, 101, 91 and 94. The insoluble ash meets all requirements in every case, while the malic acid value is low in four instances, Nos. 102, 101, 100 and 93.

GROUP 9. *Composites*. The saps from which this group of sirups was made were severally inoculated with from two to six organisms, hence the results are the product of a mixed infection. The object held in view in this procedure was to ascertain whether the presence in considerable numbers of two or more organisms would serve to stimulate or to reduce specific individual action. The flavor of all four samples was impaired, but the color was not as seriously affected. It is interesting to note that No. 19, inoculated with a mixture of fluorescent bacteria, yeasts and molds, contained a high invert sugar percentage and that the gray yeast used for inoculation purposes was the same organism employed in the inoculation of Nos. 13, 28 and 109 (table 23), in which the highest invert sugar contents obtained in this investigation were found.

TABLE 25. MAPLE SIRUP. COMPOSITES

Sample number	Color	Flavor	Score	Moisture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
19	9	3	675	32.46	63.00	2.76	0.69	0.23	0.46	0.86	0.23
116	8	4	575	29.89	67.04	0.48	0.60	0.45	0.15	0.46	1.53
118	7	4	600	29.30	67.66	0.69	0.59	0.41	0.18	0.41	1.35
119	7	2	800	28.75	68.59	0.58	0.46	0.30	0.16	0.42	1.20
Average,	7.7	3	663	30.10	66.57	1.13	0.59	0.35	0.24	0.53	1.08
Max.,	9	4	800	32.46	68.59	2.76	0.69	0.45	0.46	0.86	1.53
Min.,	7	2	575	28.75	63.00	0.48	0.46	0.23	0.15	0.41	0.23

MAPLE SIRUP. COMPOSITES

Calculated to a moisture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
19	93.28	4.09	1.02	0.34	0.68	50	127	1.27	0.34	4- 1-09
116	95.62	0.68	0.86	0.65	0.21	54	54	0.65	2.19	3-30-11
118	95.69	0.98	0.84	0.59	0.25	64	64	0.58	1.91	"
119	96.27	0.81	0.64	0.42	0.22	59	48	0.59	1.69	"
Average,	95.22	1.64	0.84	0.50	0.34	57	73	0.77	1.53	
Max.,	96.27	4.09	1.02	0.65	0.68	64	127	1.27	2.19	
Min.,	93.28	0.68	0.64	0.34	0.21	50	48	0.58	0.34	

The moisture content of the four samples in this group is low, indicating a greater density than is called for in standard sirup. It averaged 30.10% with extremes varying less than 4%.

The average sucrose content was 66.57%.

The invert sugar ranges well within the limits for average sirup, the high figure of 2.76% in No. 19, as has hitherto been pointed out, being occasioned by the activity of a gray yeast which in this and other instances exerted a pronounced inverting action on the sucrose.

The total ash is below standard in No. 119, the insoluble ash is low in Nos. 116 and 119, and the malic acid value just under the limit in Nos. 118 and 119.

GROUP 10. *Inoculated with Bacillus aceris* (new species). This organism causes a distinct type of stringiness in maple sap. It produces acid, inverts sucrose and forms gas. Fortunately for the sugar maker it does not appear to be very common in the sugar orchards. It exerts a most injurious effect on the flavor, two of the three samples inoculated scoring 4 and the other, 3. The color, while showing a depreciation from the control, does not appear to be affected to any great extent, for all three samples would have been commercially classed No. 1 in this particular. All the sirups had a cloudy appearance and the precipitated niter and other impurities settled out with difficulty. Previous to boiling the sap was quite stringy, but the resulting sirups were not especially viscid.

TABLE 26. MAPLE SIRUP. INOCULATED WITH *Bacillus aceris*

Sample number	Color	Flavor	Score	Moisture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
11	7	4	600	32.56	64.82	1.16	0.57	0.29	0.28	0.48	0.41
95	6	3	750	27.91	65.49	3.63	0.66	0.34	0.32	0.51	1.80
90	7	4	600	29.31	61.30	5.09	0.87	0.37	0.50	0.75	2.68
Average,	6.7	3.7	650	29.93	63.87	3.29	0.70	0.33	0.37	0.58	1.63
Max.,	7	4	750	32.56	65.49	5.09	0.87	0.37	0.50	0.75	2.68
Min.,	6	3	600	27.91	61.30	1.16	0.57	0.29	0.28	0.48	0.41

MAPLE SIRUP. INOCULATED WITH *Bacillus aceris*

Calculated to a moisture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
11	96.12	1.72	0.85	0.43	0.42	42	89	0.71	0.60	3-27-09
95	90.84	5.04	0.92	0.48	0.44	58	89	0.70	2.50	3-22-11
90	86.72	7.20	1.23	0.52	0.71	67	129	1.06	3.79	"
Average,	91.16	4.70	1.00	0.48	0.52	52	102	0.83	2.31	
Max.,	96.12	7.20	1.23	0.52	0.71	67	129	1.06	3.79	
Min.,	86.72	1.72	0.85	0.43	0.42	42	89	0.70	0.60	

The moisture content of these sirups varied from 27.91 to 32.56 and averaged 29.93%.

The sucrose showed relatively small variations, ranging from 61.30 to 65.49 and averaging 63.87%.

The invert sugars tend to run high, an average of 3.29% being found with extremes of 1.16 to 5.09%. The fact that

all the saps were decidedly acid after inoculation with this organism, would serve to explain the high invert sugar content.

The ash and malic acid value figures are all well above the Vermont standard.

GROUP II. *Last run, sweet.* These samples were secured late in each of three sugar seasons, 3 in 1909, 1 in 1910 and 5 in 1911. The trees were freshly tapped and clean spouts and pails used. The sap appeared bright and clear and, with one exception, was boiled down immediately after collection. Hence the conditions under which these saps were secured may be deemed to be beyond criticism.

The three samples taken in 1909 displayed exceptionally fine flavor and color, all grading 1 in flavor and 3, 7, and 5 in color and scoring 950, 850 and 900 respectively (pages 357-358). The single sample secured in 1910 and the five obtained in 1911, however, while being extremely light colored, had a pronounced "buddy" flavor, which renders a sirup particularly obnoxious for food purposes. As maple sirup is usually purchased for its flavor rather than for its sweetening properties, sirup which is thus affected is desired by neither manufacturer, dealer, nor the purchasing public.

"Buddy" sirup is secured only when a freeze occurs after the true sugar season has ended and a few warm days have started the development of the leaf buds. Sap will run on suitable days following such freezes, and if the trees are retapped and clean utensils used, the grade of goods now being considered will be secured. Should the old tap-holes, spouts and buckets be used, the material will possess a mixture of "buddy" and other objectionable flavors, due to the contamination of the spouts and pails¹. This latter condition will be again referred to in table 32 on page 455 and in the appended discussion.

¹In this connection note the statements made on pages 379 and 417 concerning "buddy" flavor and its probable origin, as well as the statement immediately succeeding table 27 on page 446.

TABLE 27. MAPLE SIRUP. LAST RUN SWEET

Sample number	Color	Flavor	Score	Moisture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Mallic acid value	Undetermined
				%	%	%	%	%	%	%	%
21	3	1	950	34.31	62.53	0.54	0.54	0.33	0.21	0.73	1.36
24	7	1	850	29.41	67.75	0.43	0.50	0.33	0.17	0.71	1.20
26	5	1	900	32.67	64.92	0.34	0.54	0.31	0.23	0.67	0.86
87	4	5	525	38.12	60.19	0.16	0.49	0.26	0.23	0.61	0.43
122	5	5	500	32.55	64.61	0.45	0.49	0.30	0.19	0.52	1.38
124	5	5	500	29.35	69.62	0.42	0.52	0.36	0.16	0.43	-0.34
126	6	5	475	32.71	63.56	0.21	*...	*...	*...	0.64	....
128	4	5	525	31.81	64.23	0.21	0.40	0.20	0.20	0.56	2.79
129	5	5	500	28.81	67.87	0.08	0.54	0.36	0.18	0.44	2.26
Average,	5	3.7	636	32.20	65.03	0.32	0.50	0.30	0.20	0.58	1.37
Max.,	7	5	950	38.12	69.62	0.54	0.54	0.36	0.23	0.73	2.79
Min.,	3	1	475	28.81	60.19	0.08	0.40	0.20	0.16	0.43	-34

 MAPLE SIRUP. LAST RUN SWEET
 Calculated to a moisture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Mallic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
21	95.19	0.82	0.83	0.50	0.33	58	91	1.11	2.05	4-12-09
24	96.02	0.61	0.71	0.47	0.24	54	54	1.01	1.65	"
26	96.42	0.51	0.80	0.46	0.34	54	62	1.00	1.27	4-16-09
87	97.27	0.26	0.79	0.41	0.38	68	145	0.98	0.52	4-3-10
122	95.80	0.67	0.73	0.45	0.28	68	59	0.76	2.04	4-21-11
124	98.54	0.59	0.74	0.52	0.22	56	47	0.61	-0.48	4-24-11
126	94.46	0.31	*...	*...	*...	*..	*..	0.95	....	"
128	94.21	0.31	0.59	0.29	0.30	48	56	0.82	4.07	4-27-11
129	95.37	0.12	0.75	0.51	0.24	59	45	0.61	3.15	4-28-11
Average,	95.92	0.47	0.74	0.45	0.29	58	70	0.87	2.00	
Max.,	98.54	0.82	0.83	0.52	0.38	68	145	1.11	4.07	
Min.,	94.21	0.12	0.59	0.29	0.22	48	45	0.61	-4.8	

*Not determined through inadvertence.

The moisture content of these sirups averaged 32.20, the maximum being 38.12 and the minimum 28.81%.

The sucrose averaged 65.03 with extremes of 60.19 and 69.62%.

The invert sugar was exceptionally small in amount, averaging only 0.32% and varying between 0.08 and 0.54%. This in itself is proof that care was taken in securing the sap and that no time was lost before boiling. The low invert sugar, together with the exceptional light color, also leads to the inference that the objectionable flavor was not caused by external contamination, but was due to some change or impurity in the sap before it left the tree, occasioned by changes occurring inside the tree, incident to the renewal of the yearly spring functions.

The total ash content runs low in 5 out of 8 samples, the average on a moisture free basis being 0.74, the maximum 0.83, and the minimum, 0.59%. The insoluble ash is low in but one instance, No. 124 being 0.01% deficient. The malic acid value meets requirements in every case.

GROUP 12. *Inoculated with fluorescent bacteria and with spore-bearers.* The saps used in securing these samples were inoculated with various strains of bacteria, mainly of the fluorescent type. Through inadvertence, spore-bearing organisms of the subtilis type commonly found in soil gained entrance¹. The results were strikingly influenced by the presence and action of these spore-bearing organisms. The flavor was seriously injured, 4 out of 7 samples grading 4 (poor) and the rest of them 3 (medium). The color was darkened several shades and showed a large depreciation as compared with the controls, although none were classed below a No. 2, as commercially rated. By comparison with the results obtained with fluorescent organisms alone, it appears that the color injury should be attributed largely to the introduced species, while the intruder is doubtless chiefly responsible for the ill flavor and the high invert sugar content.

¹ See statement concerning this matter, page 377.

TABLE 28. MAPLE SIRUP. INOCULATED WITH FLUORESCENT BACTERIA AND OTHER ORGANISMS AND WITH SPORE-BEARERS

Sample number	Color	Flavor	Score	Molsture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
75	9	3	675	40.32	50.57	6.43	0.78	0.26	0.52	0.73	1.17
76	10	3	650	38.02	53.94	5.54	0.80	0.34	0.46	0.76	0.94
77	8	3	700	39.67	53.17	4.97	0.79	0.34	0.45	0.80	0.60
78	8	4	575	39.98	50.33	6.29	0.74	0.24	0.50	0.71	1.95
79	7	4	600	47.60	41.28	7.99	0.67	0.19	0.48	0.74	1.72
80	10	4	525	45.03	43.54	8.81	0.72	0.24	0.48	0.73	1.17
81	7	4	600	38.72	54.68	4.60	0.69	0.34	0.35	0.66	0.65
Average,	8.4	3.6	618	41.33	49.64	6.38	0.74	0.27	0.47	0.73	1.18
Max.,	10	4	700	47.60	54.68	8.81	0.80	0.34	0.52	0.80	1.95
Min.,	7	3	525	38.02	41.28	4.60	0.67	0.19	0.35	0.66	0.60

MAPLE SIRUP. INOCULATED WITH FLUORESCENT BACTERIA AND OTHER ORGANISMS AND WITH SPORE-BEARERS

Calculated to a moisture-free basis

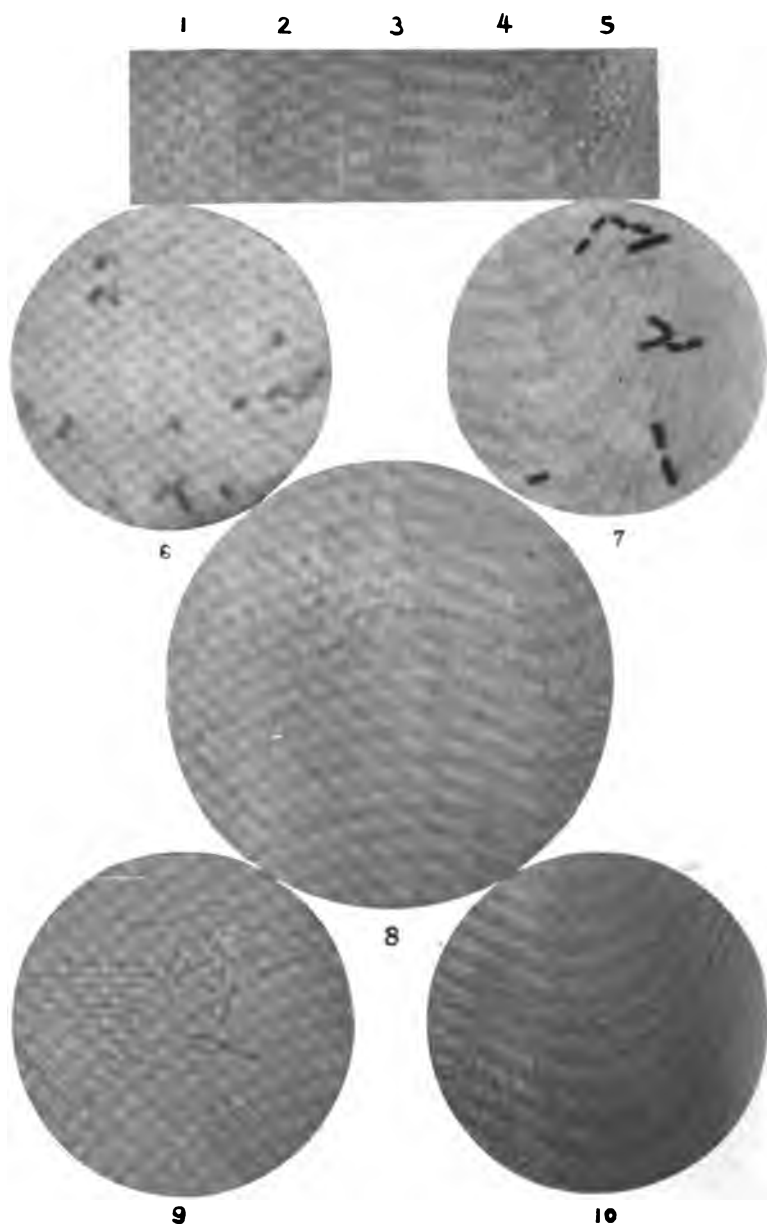
Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
75	84.74	10.77	1.30	0.43	0.87	71	118	1.22	1.97	3-24-10
76	87.03	8.94	1.29	0.54	0.75	59	70	1.23	1.51	"
77	88.13	8.24	1.31	0.56	0.75	62	86	1.32	1.00	"
78	83.86	10.48	1.24	0.40	0.84	61	169	1.18	3.24	"
79	78.78	15.25	1.28	0.36	0.92	64	184	1.42	3.27	"
80	79.20	16.03	1.30	0.43	0.87	61	175	1.32	2.15	"
81	89.23	7.51	1.12	0.56	0.56	62	50	1.07	1.07	"
Average,	84.42	11.03	1.26	0.46	0.80	63	122	1.25	2.04	
Max.,	89.23	16.03	1.31	0.56	0.92	71	184	1.42	3.27	
Min.,	78.78	7.51	1.12	0.36	0.56	59	50	1.07	1.00	

The entire lot of 7 samples were a light weight sirup, the moisture content running from 47.60 to 38.02 and averaging 41.33%. The sucrose is low owing to the high water and invert sugar content, averaging but 49.64, with extremes of 41.28 and 54.68%. The invert sugar runs uniformly high and without the extreme variations noted in some of the previous groups. The extremes are 4.60 and 8.81 with an average of 6.38%, which, on the moisture free basis, is equivalent to 11.03%. The ash and malic acid value data are well above standard.

GROUP 13. *Inoculated with green molds.* The organisms here used are the ordinary green molds frequently seen on stale bread. While of common occurrence, they do not grow vigorously at low temperatures, hence they are of minor importance so far as maple sap is concerned; but probably no other single group of organisms does so much damage to sirup after its manufacture. When introduced into the sap, they seriously impaired both the flavor and color of the resulting sirup, 3 out of the 4 samples grading 4 in flavor, corresponding to poor quality, while the color showed a depreciation of over 4 points from the control. The content of invert sugar was also noticeably increased.



PLATE VII.—Colonies developing on nutrient agar and on synthetic agar, respectively, from one-two thousandth of a cubic centimeter of maple sap No. 67 received in wooden buckets. (See pages 343, 373.)



9 10
 PLATE VIII.—*Bacillus aceris*. Figures 1-5. Successive photographs of living organisms during fission. Figure 6. Flagella preparations. Löwet's stain. Figure 7. Stained preparation, gentian violet. Figure 8. Living organisms showing chains in motion. Figures 9 and 10. Living organisms on agar, showing orientation. (See pages 480-482.) $\times 1350$.

TABLE 29. MAPLE SIRUP. INOCULATED WITH GREEN MOLDS

Sample number	Color	Flavor	Score	Moisture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
16	10	4	525	32.86	64.27	1.75	0.72	0.24	0.48	0.49	-0.09
17	10	2	725	34.08	61.15	2.29	0.72	0.20	0.52	0.95	0.81
111	7	4	600	28.29	66.91	3.15	0.55	0.38	0.17	0.48	0.62
117	9	4	550	30.70	63.12	2.58	0.51	0.35	0.16	0.42	2.67
Average,	9	3.5	600	31.48	63.86	2.44	0.63	0.30	0.33	0.58	1.01
Max.,	10	4	725	34.08	66.91	3.15	0.72	0.38	0.52	0.95	2.67
Min.,	7	2	525	28.29	61.15	1.75	0.51	0.20	0.16	0.42	-0.09

MAPLE SIRUP. INOCULATED WITH GREEN MOLDS

Calculated to a moisture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
16	95.73	2.61	1.07	0.36	0.71	39	140	0.72	-0.13	4- 1-09
17	92.76	3.47	1.09	0.30	0.79	46	161	1.44	1.24	"
111	93.31	4.39	0.77	0.53	0.24	61	57	0.67	0.86	3-27-11
117	91.09	3.72	0.74	0.51	0.23	64	52	0.61	3.84	3-30-11
Average,	93.21	3.56	0.92	0.44	0.48	52	103	0.86	1.45	
Max.,	95.73	4.39	1.09	0.53	0.79	64	161	1.44	3.84	
Min.,	91.09	2.61	0.74	0.30	0.23	39	52	0.61	-0.13	

The moisture shows less variation than usual, the extremes being 34.08 and 28.29 and the average 31.48%. The sucrose averages 63.86, with a minimum of 61.15, and a maximum of 66.91%. The invert sugar figures run fairly high, the extremes being 1.75 and 3.15 and the average 2.44%. Three green mold organisms were used in the inoculation of these samples and

they all appear to exert a marked inverting action on sucrose. The total and insoluble ashes together with malic acid value are above standard in all cases.

GROUP 14. *Tin vs. wooden buckets.* The sap from 6 trees was used in this phase of the work. All tap-holes, spouts and utensils were made strictly clean and the procedures were identical in both cases. The sap was concentrated as soon as collected. That obtained in the tin buckets ran 2 days earlier than that gathered in the wooden buckets, but, as a check, in order to be certain that the two days' intermission exercised no influence on the results, bacterial counts were made on sap obtained in tin buckets from the same trees and spouts after the close of the experiment. It was practically free from bacteria of any kind; (see page 343). The grade of sirup produced from the tin buckets (No. 66) was of the highest quality, ranking 1 in flavor and 3 in color, and scoring 950. That secured from the wooden buckets (No. 67), in marked contrast to that made when tin buckets were employed, ranked only 4 in flavor, 9 in color and scored but a total of 550 points out of a possible 975. Furthermore its invert sugar content was high, there being seventeen times as much present in the sirup secured in the wooden buckets as was found in that made when tin buckets were used. This is doubtless to be attributed to the organisms already existing in the wooden buckets since, although thoroughly cleansed, they were not new and were painted on the outside only.

Both sirups were light in weight containing respectively 37.78 and 38.33 percents of water.

The sucrose is considerably higher in No. 66 than in No. 67, owing to its low invert sugar content.

The standards for ash and malic acid value are fully met by both samples.

TABLE 30. MAPLE SIRUP. TIN VS. WOODEN BUCKETS

Sample number	Color	Flavor	Score	Moisture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Mallic acid value	Undetermined
				%	%	%	%	%	%	%	%
66	3	1	950	37.78	60.12	0.25	0.49	0.31	0.18	0.52	0.84
67	9	4	550	38.33	54.42	4.26	0.62	0.34	0.28	0.73	1.64

MAPLE SIRUP. TIN VS. WOODEN BUCKETS

Calculated to a moisture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Mallic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
66	% 96.62	% 0.41	% 0.78	% 0.49	% 0.29	65	59	% 0.4	% 1.35	3-22-10
67	% 88.25	% 6.91	% 1.01	% 0.55	% 0.46	63	103	% 1.19	% 2.64	3-24-10

GROUP 15. *Inoculated with pink yeast; burned control.*

These two samples, while grouped together, bear no relation to each other. The pink yeasts are not as common as are the red and gray yeasts previously mentioned, but, like them, are encountered late in the season. The effect on sirup made from sap inoculated with pink yeast is shown in No. 98, which may be considered a typical yeast sirup. Both flavor and color were impaired, particularly the former. The sirup ranked poor in quality and, while grading commercially as No. 2, showed a color depreciation of 6 points. This organism exerted a marked inverting action on the sucrose, but the other results, including those for ash and malic acid value, are normal in spite of the increased concentration, indicated by the low moisture content of 29.26%.

The burned sample, No. 74, listed in this table, was a control on the fluorescent and spore-bearer series shown in table 12. It was slightly burned, so that the flavor and color were seriously affected. The burning had but little if any effect on the invert sugar percentage, as only 0.70% calculated to the moisture free basis was found.

TABLE 31. MAPLE SIRUP. INOCULATED WITH PINK YEAST; BURNED CONTROL

Sample number	Color	Flavor	Score	Molsture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
98	9	4	550	% 29.26	% 61.33	% 6.15	% 0.59	% 0.37	% 0.22	% 0.50	% 2.17
74	9	4	550	41.40	56.47	0.41	0.73	0.24	0.49	0.77	0.22

MAPLE SIRUP. INOCULATED WITH PINK YEAST; BURNED CONTROL

Calculated to a molsture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
98	% 86.70	% 8.69	% 0.83	% 0.52	% 0.31	62	74	% 0.71	% 3.07	3-26-11
74	96.36	0.70	1.24	0.41	0.83	51	99	1.31	0.39	3-24-10

GROUP 16. *Last run sour.* The sirups thus listed were made from sap which was collected late in the season, and which was cloudy as it dripped from the spout. The tap-holes, spouts and buckets were contaminated. In every case but one the sap was evaporated on the same day it ran.

Referring to the column headed flavor in the following table, it will be noted that the three samples, Nos. 22, 23 and 25, secured late in the season of 1909, graded 3 in flavor, corresponding to medium quality, and 8, 14 and 14 respectively in color, indicating the second and third grades. No "buddy" sirup was obtained in 1909. The sirups secured in 1910 and 1911 graded 5 or 6 in flavor indicating buddiness or worse than buddiness. The color in all but Nos. 121 and 125 was seriously affected, grading from 11 to 15.

TABLE 32. MAPLE SIRUP. LAST RUN SOUR

Sample number	Color	Flavor	Score	Moisture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
22	8	3	700	34.45	62.45	1.81	0.64	0.42	0.22	0.87	-0.22
23	14	3	550	34.73	60.41	2.32	0.74	0.40	0.34	0.58	1.22
25	14	3	550	38.68	57.67	1.92	0.86	0.26	0.60	1.15	-0.28
88	11	6	250	35.57	60.93	1.15	0.80	0.35	0.45	0.83	0.72
121	7	5	450	35.85	60.26	0.22	0.59	0.25	0.35	0.69	0.39
123	11	6	250	34.01	62.82	0.42	0.54	0.28	0.26	0.55	1.66
125	7	5	450	35.67	60.39	0.34	0.53	0.27	0.26	0.58	2.49
127	15	6	150	33.36	58.25	3.06	0.80	0.32	0.48	0.85	3.68
130	12	6	225	33.41	62.50	0.89	0.68	0.34	0.34	0.65	1.87
Av'ge,	11	4.8	397	35.08	60.63	1.35	0.68	0.31	0.37	0.75	1.51
Max.,	15	6	700	38.68	62.82	3.06	0.86	0.42	0.60	1.15	3.68
Min.,	7	3	150	33.36	57.67	0.22	0.53	0.25	0.22	0.55	-0.28

 MAPLE SIRUP. LAST RUN SOUR
 Calculated to a moisture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
	%	%	%	%	%			%	%	
22	95.27	2.76	0.98	0.64	0.34	85	76	1.33	-0.34	4-12-09
23	92.56	3.55	1.13	0.61	0.52	58	172	0.90	1.86	"
25	94.05	3.13	1.40	0.42	0.98	98	173	1.87	-0.45	4-16-09
88	94.56	1.79	1.24	0.54	0.70	52	173	1.29	1.12	4- 3-10
121	93.94	0.34	0.91	0.38	0.53	59	98	1.08	3.73	4-21-11
123	95.33	0.64	0.83	0.43	0.40	56	73	0.84	2.36	4-24-11
125	93.88	0.53	0.82	0.41	0.41	53	94	0.90	3.87	"
127	87.41	4.59	1.20	0.49	0.71	59	144	1.28	5.52	4-27-11
130	93.86	1.34	1.03	0.52	0.57	71	99	0.98	2.79	4-28-11
Average,	93.41	2.07	1.05	0.48	0.57	64	122	1.16	2.31	
Max.,	95.33	4.59	1.40	0.64	0.98	98	173	1.87	5.52	
Min.,	87.41	0.34	0.82	0.38	0.34	52	73	0.84	-0.45	

The moisture content of these sirups showed less variation than has been noted in many of the groups. The average was 35.08, with extremes of 38.68 and 33.36%.

The sucrose averaged 60.63, with extremes of 57.67 and 62.82%.

The invert sugar averaged 1.35%. Nos. 121, 123 and 125 contained but small amounts, which serves to show that in these cases the infecting organism did not act as an invert sugar former. The remaining samples, however, show quite a marked increase, the invert sugar content of No. 127 being 3.06%.

The total and insoluble ash and malic acid value are well above the standard in every case.

GROUP 17. *Sour sap, kept.* The three samples thus listed were secured in 1910 just previous to the buddy sample No. 88 mentioned in table 32. They represent a composite of the small runs during several days toward the close of the season. Tap-holes, spouts and pails were contaminated through the ordinary natural sources, as was indicated by the cloudy appearance of the running sap. The flavor in each case was a poor medium. The color of No. 84 was darker than that of any other sample secured, with two exceptions grading 20, the extreme limit on the colorimetric scheme. Nos. 85 and 86 were even darker than No. 84 and defied grading. An attempt was made during the boiling process to clarify No. 86 by means of the usual white of egg treatment which, in this case at least, was ineffective.

TABLE 33. MAPLE SIRUP. FROM SOUR SAP KEPT

Sample number	Color	Flavor	Score	Moisture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
				%	%	%	%	%	%	%	%
84	20	3 ¹	350	33.67	60.45	1.88	0.99	0.34	0.65	0.65	2.36
85	20+	3 ¹	325	36.67	59.96	0.99	0.89	0.23	0.66	0.73	0.76
86	20+	3 ¹	325	34.72	60.85	0.81	0.91	0.27	0.64	0.82	1.89
Av'ge,	20	3 ¹	333	35.02	60.42	1.23	0.93	0.28	0.65	0.73	1.67
Max.,	20+		350	36.67	60.85	1.88	0.99	0.34	0.66	0.82	2.36
Min.,	20		325	33.67	59.96	0.81	0.89	0.23	0.64	0.65	0.76

MAPLE SIRUP. FROM SOUR SAP KEPT
Calculated to a moisture-free basis

Sample number	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value	Undetermined	Date
						Soluble ash	Insoluble ash			
84	91.14	2.83	1.50	0.51	0.99	75	122	0.98	3.55	4- 2-10
85	94.68	1.57	1.41	0.37	1.04	63	130	1.15	1.19	"
86	93.21	1.23	1.40	0.42	0.99	65	137	1.26	2.90	"
Average,	93.00	1.88	1.44	0.43	1.01	68	130	1.13	2.55	
Max.,	94.68	2.83	1.50	0.51	1.04	75	137	1.26	3.55	
Min.,	91.14	1.23	1.40	0.37	0.99	63	122	0.98	1.19	

The moisture content of the three sirups varied from 36.67 to 33.67, averaging 35.02%.

The sucrose content was quite uniform and averaged 60.42%.

The invert sugar percentages were 1.88, 0.99 and 0.81, averaging 1.23%. These figures are low enough to indicate that, although the contaminating organisms were very abundant, bacterial counts showing over 11,000,000 per cc., they were relatively inactive as producers of invert sugar from sucrose. As has been stated the color of the sirup was most seriously affected.

Both the total and insoluble ash contents as well as the malic acid values were above standard.

SUMMARY OF AVERAGES SECURED ON THE SUNDRY GROUPS DISCUSSED

Table 34 displays the averages of the individual analyses of the several sirups examined, in the order previously discussed, together with the average for the 128 samples. The differences in physical characteristics and chemical composition are indicated in the original material and the moisture-free basis portions of the table.

The color averages 7.5, corresponding closely to first grade. The darkest color was obtained in the samples located in the "sour sap, kept" group. This group also showed the highest depreciation from the control as regards color. The lightest color was secured in samples grouped under the captions "tin buckets" and "control."

The flavor averages 2.9, corresponding to a quality just below medium. The finest flavor was obtained in samples grouped under the term "tin buckets" and "control" rating as 1 and 1.4 respectively, the poorest sample in this respect was located in the group denominated "last run, sour," which included several buddy sirups. Excluding the samples rating 5 and 6 in flavor (buddy) from the color and flavor averages, the average color and flavor figures thus revised for the remaining 116 samples are 7.5 and 2.6 respectively, equivalent to an average score of 719.

TABLE 34. AVERAGE ANALYSES OF THE MAPLE SIRUP GROUPS

Group number	Character of organism	Color	Flavor	Score	Moisture	Sucrose	Invert sugar	Total ash	Soluble ash	Insoluble ash	Malic acid value	Undetermined
					%	%	%	%	%	%	%	%
1	Control	3.8	1.4	911	34.06	68.51	0.39	0.52	0.28	0.24	0.57	0.95
2	Incubator control	5.4	2.0	827	36.78	60.41	0.65	0.57	0.29	0.28	0.55	1.04
3	Non-fluorescent	5.5	2.5	800	34.70	62.36	0.99	0.69	0.27	0.42	0.57	0.69
4	Pink cocci	5.7	2.6	775	37.15	59.05	1.54	0.54	0.28	0.26	0.50	1.22
5	Failures	7.0	2.3	772	34.99	62.48	0.33	0.65	0.29	0.36	0.52	1.03
6	Red yeasts	8.0	2.8	703	35.48	60.36	2.05	0.62	0.30	0.32	0.61	0.88
7	Gray yeasts	7.3	3.2	678	35.60	57.78	4.42	0.60	0.32	0.28	0.59	1.01
8	Fluorescent	9.0	2.9	665	32.23	64.79	0.74	0.63	0.31	0.32	0.55	1.06
9	Composite	7.7	3.0	663	30.10	66.57	1.13	0.59	0.35	0.24	0.53	1.08
10	<i>Bacillus acris</i>	6.7	3.7	650	29.93	63.87	3.29	0.70	0.33	0.37	0.58	1.63
11	Last run, sweet	5.0	3.7	636	32.20	65.03	0.32	0.50	0.30	0.20	0.58	1.37
12	Flour. and spore-bearers..	8.4	3.6	618	41.33	49.64	6.38	0.74	0.27	0.47	0.73	1.18
13	Green molds	9.0	3.5	600	31.48	63.86	2.44	0.63	0.30	0.33	0.58	1.01
14	Tin buckets	3.0	1.0	950	37.78	60.12	0.25	0.49	0.31	0.18	0.52	0.84
14	Wooden buckets	9.0	4.0	550	38.53	54.42	4.26	0.62	0.34	0.28	0.73	1.64
15	Pink yeasts	9.0	4.0	550	29.26	61.33	6.15	0.59	0.37	0.22	0.50	2.17
15	Burned control	9.0	4.0	550	41.40	56.47	0.41	0.73	0.24	0.49	0.77	0.52
16	Last run, sour	11.0	4.8	397	35.08	60.63	1.35	0.68	0.31	0.37	0.75	1.51
17	Sour sap, kept	20.0	3.1	333	35.02	60.42	1.23	0.93	0.28	0.65	0.73	1.67
	Average	7.5	2.9	689	34.63	61.44	1.60	0.61	0.29	0.32	0.59	1.13

AVERAGE ANALYSES OF THE MAPLE SIRUP GROUPS
Calculated to a moisture-free basis

Group number	Character of organism	Sucrose %	Invert sugar %	Total ash %	Soluble ash %	Insoluble ash %	ALKALINITY		Malic acid value %	Undetermined	Number of samples
							Soluble ash	Insoluble ash			
1	Control	96.32	0.60	0.77	0.41	0.36	51	77	0.86	1.45	11
2	Incubator control	95.55	1.04	0.90	0.46	0.44	61	92	0.87	1.64	13
3	Non-fluorescent	95.50	1.52	1.06	0.42	0.64	46	132	0.87	1.05	4
4	Pink cocci	93.94	2.45	0.86	0.45	0.41	61	83	0.79	1.96	6
5	Fallures	96.13	0.51	1.00	0.45	0.55	59	98	0.80	1.56	8
6	Red yeasts	93.54	3.18	0.96	0.47	0.49	58	101	0.91	1.41	13
7	Gray yeasts	89.72	6.86	0.94	0.50	0.44	59	95	0.92	1.56	8
8	Fluorescent	95.42	1.09	0.93	0.46	0.47	59	95	0.82	1.74	22
9	Composite	95.22	1.64	0.84	0.50	0.34	57	73	0.77	1.53	4
10	Bacillus aceris	91.16	4.70	1.00	0.48	0.52	52	102	0.83	2.31	3
11	Last run, sweet	95.92	0.47	0.74	0.45	0.29	58	70	0.87	2.00	9
12	Fluor. bac. & spore bearers	84.42	11.03	1.26	0.46	0.80	63	122	1.25	2.04	7
13	Green molds	93.21	3.56	0.92	0.44	0.48	52	103	0.86	1.45	4
14	Tin buckets	96.62	0.41	0.78	0.49	0.29	65	59	0.84	1.35	1
14	Wooden buckets	88.25	6.91	1.01	0.55	0.46	36	103	1.19	2.64	1
15	Pink yeasts	86.70	8.69	0.83	0.52	0.31	62	74	0.71	3.07	1
15	Burned, control	96.36	0.70	1.24	0.41	0.83	51	99	1.31	0.39	1
16	Last run, sour	93.41	2.07	1.05	0.48	0.57	64	122	1.16	2.31	9
17	Sour sap, kept	93.00	1.88	1.44	0.43	1.01	68	130	1.13	2.55	3
	Average	93.99	2.45	0.93	0.44	0.49	59	97	0.90	1.73	
	Maximum	96.62	11.03	1.44	0.55	1.01	68	132	1.31	3.07	
	Minimum	84.42	0.41	0.74	0.41	0.29	36	59	0.71	0.39	

The average moisture content for the entire 128 samples is 34.63%. This is practically the moisture percentage of a standard eleven-pound to the gallon sirup.

The average sucrose figures 61.44%, and the invert sugar percentage, 1.60%, agree quite closely with the averages, 62.64% and 1.49%, secured by Bryan in an examination of 395 samples from all parts of the United States where maple products are made.

The average total ash figure on a moisture free basis is 0.93%, and extremes are 0.74 and 1.44%. The minimum figures occur in the "last run, sour" group and include considerable number of buddy sap samples.

The average insoluble ash percentage is well over the standard in every group, the minimum being 0.29, the maximum 1.01, and the average 0.59%.

The malic acid value is likewise above the standard limit, with a minimum of 0.71, a maximum of 1.21, and an average of 0.90%.

The grand average for the 128 samples secured in the three sugar seasons is in every particular typical of pure maple sirup, and would of course more nearly represent the output of that particular sugar orchard than would any single sample or minor group of samples.

INVERT SUGAR CONTENT OF MAPLE SIRUP

The invert sugar present in the sirups obtained in this investigation shows extremes, calculated to a moisture-free basis, of 0.12 and 28.35%. Invert sugar results from the hydrolysis or inversion of sucrose, caused by yeasts, molds, bacteria, acids, etc. Thirty-two sirups, or a quarter part of the entire number of samples, carried less than 0.60% of invert sugar on a moisture-free basis, while 57 samples, or 45%, contained less than 1%. Hence it seems fair to conclude that an invert sugar content in maple sirup of much more than 1% can only be due to careless methods in handling or to delay in boiling the sap, or to the subsequent fermentation of the finished product.

The average invert sugar in the sirups examined, together with the maximum and minimum amounts found in the individual samples, are summarized in table 35 in the order of their magnitude.

TABLE 35. AVERAGE INVERT SUGAR CONTENT OF THE DIFFERENT GROUPS AND MAXIMUM AND MINIMUM IN INDIVIDUAL SAMPLES

Group number	Character of organism	INVERT SUGAR Calculated to a moisture-free basis		
		Average	Maximum	Minimum
		%	%	%
14	Tin buckets	0.41	*	*
11	Last run, sweet	0.47	0.82	0.12
5	Failures	0.51	0.90	0.23
1	Control	0.60	1.58	0.19
15	Burned control	0.70	*	*
2	Incubator control	1.04	3.52	0.41
8	Fluorescent	1.09	2.46	0.38
3	Non-fluorescent	1.52	2.38	0.77
9	Composite	1.64	4.09	0.68
17	Sour sap, kept	1.88	2.83	1.23
16	Last run, sour	2.07	4.59	0.34
4	Pink cocci	2.45	7.90	0.65
6	Red yeasts	3.18	7.63	1.01
13	Green molds	3.56	4.39	2.61
10	Bacillus acris	4.70	7.20	1.72
7	Gray yeasts	6.86	28.35	1.21
14	Wooden buckets	6.91	*	*
15	Pink yeasts	8.69	*	*
12	Fluorescent bacteria and spore-bearers	11.03	16.03	7.51

*Single sample.

It is readily seen that the average invert sugar figures show a fairly regular gradation from 0.41 to 11.03%, but that the maximum and minimum figures among the different groups exhibit wide variations. Thus the average for group 7, gray yeasts, is 6.86%, but it is obtained by averaging eight results, which vary all the way from 1.21 to 28.35%. These differences in the maximum and minimum figures found in the same group are doubtless due to the fact that certain strains produced a more complete infection and were better inverters of sucrose than were others. Certain of the organisms used, notably those of the fluorescent group, had but little effect on the sucrose. They

apparently feed mainly on the proteids and mineral salts and exert a detrimental influence on color and flavor. Generally speaking, the yeasts and molds, which often but not always thrive well in a slightly acid medium, together with the spore-bearing bacteria, had the most pronounced inverting action on sucrose, either through the production of invertase, or by the formation of acid, or both. In many cases they likewise seriously affected color and flavor.

Most of the remaining bacteria used in this work did not prove particularly active as invert sugar makers, but their harmful effect was in many instances manifested by the color and flavor of the sirup.

DISCUSSION OF THE TOTAL AND INSOLUBLE ASH AND MALIC ACID VALUES

A survey of the analytical data given in tables 16 to 34 shows that the ash and malic acid values of 34 of the samples examined were slightly below the standards used in determining the purity of maple products. These deficiencies have been noted in the discussion of the several groups. The question now arises whether these abnormalities, which in many cases are very slight, are due:

(1) To the exceptional conditions obtaining in these experimental trials of the manufacture of sirup from sap, e. g., the small amounts of sap evaporated, the small number of trees contributing to the individual samples, and the variation in density of the resulting sirup.

(2) To the treatment of the sirups after manufacture and previous to analysis.

(3) To the effect of the inoculating organisms on the physical characteristics and chemical composition of the sirups.

These considerations have been clearly explained in the preceding pages, but their connection with the analytical data under discussion has not been traced.

For the purpose of easy reference and to assign, if possible, a definite reason for these failures, all samples showing defi-

ciencies in ash or malic acid values are listed by groups in the following table.

TABLE 36. SIRUPS DEFICIENT IN TOTAL ASH, INSOLUBLE ASH, OR MALIC ACID VALUE

Group number	Character of organism	Sample number	Moisture	Sucrose	Invert sugar	CALCULATED TO MOISTURE-FREE BASIS			
						Total ash	Soluble ash	Insoluble ash	Malic acid value
			%	%	%	%	%	%	%
1	Control,	27	34.46	63.04	0.20	0.75	0.53	0.22	0.73
	"	58	36.30	61.80	0.28	0.73	0.43	0.30	0.83
	"	68	37.33	60.73	0.32	0.68	0.45	0.23	0.81
	"	89	29.96	67.11	0.24	0.61	0.32	0.29	1.01
	"	97	30.36	66.88	0.13	0.68	0.43	0.25	0.73
	"	113	29.99	67.89	0.43	0.75	0.50	0.25	0.73
2	Inc. cont'l,	96	27.81	68.82	0.32	0.71	0.46	0.25	0.65
	" "	104	29.46	68.42	0.29	0.69	0.47	0.22	0.60
	" "	112	31.34	67.01	0.76	0.71	0.50	0.21	0.44
	" "	120	38.97	58.06	0.35	0.71	0.45	0.26	0.72
4	P'k cocci,	107	27.90	68.15	0.50	0.71	0.50	0.21	0.58
	" "	31	38.21	59.70	0.19	1.14	0.55	0.59	0.55
5	Failures,	106	30.48	67.64	0.46	0.69	0.47	0.22	0.59
	"	108	29.64	67.10	0.63	0.65	0.45	0.20	0.49
6	R. yeasts,	114	30.69	66.75	0.70	0.71	0.49	0.22	0.56
	"	99	28.11	68.17	1.47	0.75	0.44	0.31	0.67
7	G. yeasts,	110	30.94	67.05	1.20	0.67	0.44	0.23	0.65
	"	115	31.04	65.61	1.05	0.72	0.51	0.21	0.62
8	Flu. bac.,	102	28.81	68.11	0.81	0.82	0.58	0.24	0.50
	"	103	28.75	67.97	0.96	0.73	0.45	0.28	0.60
	"	101	28.36	69.10	0.67	0.71	0.44	0.27	0.53
	"	100	27.76	69.59	0.67	0.79	0.54	0.25	0.55
	"	91	26.75	69.40	0.29	0.72	0.44	0.28	0.90
	"	93	28.06	68.65	0.31	0.83	0.56	0.27	0.54
	"	94	28.51	67.69	0.37	0.72	0.41	0.31	0.64
9	Comp'te,	116	29.89	67.04	0.48	0.86	0.65	0.21	0.65
	"	118	29.30	67.66	0.69	0.84	0.59	0.25	0.58
	"	119	28.75	68.59	0.58	0.64	0.42	0.22	0.59
11	Last run,								
	sweet,	24	29.41	67.75	0.43	0.71	0.47	0.24	1.01
	"	122	32.55	64.61	0.45	0.73	0.45	0.28	0.76
	"	124	29.35	69.62	0.42	0.74	0.52	0.22	0.61
	"	128	31.81	64.23	0.21	0.59	0.29	0.30	0.82
	"	129	28.81	67.87	0.08	0.75	0.51	0.24	0.61
13	G. molds,	117	30.70	63.12	2.58	0.74	0.51	0.23	0.61
	Average,		30.62	66.50	0.57	0.74	0.48	0.26	0.66
	Maximum,		38.97	69.62	2.58	1.14	0.65	0.59	1.01
	Minimum,		26.75	58.06	0.08	0.59	0.29	0.20	0.44

This table, studied in conjunction with its predecessors, shows:

(1) That the color averaged 6, with extremes of 3 and 9, indicating that in all cases the goods were of high grade.

(2) That the flavor ranged from 1 to 5 with an average of 3, which corresponds to medium. Of the 34 samples listed, 4 scored 1 in flavor, 9 scored 2, 7 scored 3, 10 scored 4, and 4 scored 5 (buddy). In other words 20 samples or 3 out of 5 graded medium or better than medium.

(3) That 10 of the 34 samples were "controls," that 5 were "last run sap, sweet," that 1 was inoculated with green mold, 6 with yeasts, 8 with bacteria, and 3 with mixtures of yeasts and bacteria. Hence, 15, or 44% of the total number, were not artificially inoculated.

(4) That invert sugar was not formed in excessive amounts.

(5) That most of the samples contained far less water than the 35% which the standard 11 pounds to the gallon sirup carries. They were, consequently, considerably heavier than necessary. But 4 samples contained more than 35% of water, while thirty carried from 26.75 to 34.46%, and twenty less than 30% of water.

The standards of ash and malic acid used were predicated on an eleven-pound gallon, or 35% moisture, basis. It is quite evident that the over-concentration secured in these samples together with their thorough clarification before analysis, resulted in an increased precipitation and sedimentation of the "niter," greater than would have occurred had the sap sirup been concentrated only to the standard density. This tended to lower the ash and malic acid contents of the sample as analysed. This is strikingly brought out by a comparison of the analyses of samples containing over 34% water with those containing less than this amount as shown on the next page.

	No. of samples	Moist- ure	Calculated to a moisture-free basis			
			Total ash	Soluble ash	In- soluble ash	Malic acid value
Average,	128	34.63	0.93	0.44	0.49	0.90
Average above 34% water,	84	36.86	1.02	0.45	0.57	1.00
Average below 34% water,	42	30.05	0.80	0.48	0.32	0.71
Average below 30% water,	25	28.74	0.77	0.49	0.28	0.66

A gradual drop in the total and insoluble ash contents and in malic acid value occurs as the concentration increases. If averages show this condition, it is to be expected that the individual samples, which, in the instances under consideration, represent the sap from but a few trees and not a composite from the orchard, would show similar variations, some of which must of necessity be below the standard of comparison, which, of course, is based on commercial samples and not on such extreme conditions as obtained in this investigation.

In judging the purity of maple sirup, it is essential that the analyst should clearly understand the nature and significance of the data secured. The standard under consideration includes the total and insoluble ash contents and the malic acid value. They represent inorganic and organic constituents respectively. The slight departure of any one constituent from the standard should not in itself be interpreted too strictly, particularly if it be the total ash or malic acid value.

The number of samples below the standard, and the average, maximum and minimum deficiencies are stated in the following table.

TABLE 37. NUMBER OF SAMPLES AND PERCENT BELOW STANDARD IN TOTAL ASH, INSOLUBLE ASH AND MALIC ACID VALUE

CALCULATED TO MOISTURE-FREE BASIS												
Character of organism		Total ash				Insoluble ash				Malic acid value		
		Below 0.77%	Percent below			Below 0.23%	Percent below			Below 0.60%	Percent below	
			Average	Maximum			Minimum	Average			Maximum	Minimum
Control,	6	.07	.16	.02	1	.01	...	...	0	...	...	...
Inc. con.,	4	.07	.08	.06	2	.01	.02	.01	1	.16	...	...
Non-fluo.,	0	...	...	...	0	...	...	...	0	...	...	...
P'k cocci,	1	.06	...	...	1	.02	...	...	1	.02	...	...
Failures,	2	.10	.12	.08	2	.02	.03	.01	3	.06	.11	.01
R. yeasts,	2	.04	.06	.02	1	.01	...	...	1	.04	...	...
G. yeasts,	2	.07	.10	.05	1	.02	...	...	0	...	...	...
Fluores't,	4	.05	.06	.04	0	...	...	...	4	.07	.10	.05
Comp'te,	1	.13	...	...	2	.01	.02	.01	2	.01	.02	.01
<i>B. aceris</i> ,	0	...	...	...	0	...	...	...	0	...	...	...
Last run,												
sweet,	5	.07	.18	.02	1	.01	...	...	0	...	...	...
Fluor. bac.												
and spore-												
bearers,	0	...	...	...	0	...	...	...	0	...	...	...
G. molds,	1	.03	...	...	0	...	...	...	0	...	...	...
T. buck's,	0	...	...	...	0	...	...	...	0	...	...	...
W. buck's,	0	...	...	...	0	...	...	...	0	...	...	...
P. yeasts,	0	...	...	...	0	...	...	...	0	...	...	...
Burned												
control,	0	...	...	...	0	...	...	...	0	...	...	...
Last run,												
sour,	0	...	...	...	0	...	...	...	0	...	...	...
Sour sap,												
kept,	0	...	...	...	0	...	...	...	0	...	...	...
Total,	28				11				12			

Twenty-eight samples were deficient in total ash in amounts varying from 0.02 to 0.18%. The deficiencies mainly occur among samples in the control groups. Eleven samples were low in insoluble ash, but the shortages were very slight, varying from 0.01 to 0.03%, the latter figure occurring but once. There were 12 deficiencies in malic acid values, many of them being very small and ranging from 0.01 to 0.16%.

Inquiring still farther into these deficiencies, it will be found that in several cases but a single item of the three-fold standard is affected. Eliminating the groups exhibiting no departures from standard, the following table appears.

TABLE 38. NUMBER AND NATURE OF DEFICIENCIES

Group number	Character of organism	Low in total ash	Low in insoluble ash	Low in malic acid value	Low in total and insoluble ash	Low in total ash and malic acid value	Low in insoluble ash and malic acid value	Low in total ash, insoluble ash and malic acid value
1	Control	6	1	0	1	0	0	0
2	Incubator control	4	2	1	1	0	0	1
4	Pink cocci	1	1	1	0	0	0	1
5	Failures	2	2	3	0	0	0	2
6	Red yeasts	2	1	1	0	0	0	1
7	Gray yeasts	2	1	0	1	0	0	0
8	Fluorescent	4	0	4	0	1	0	0
9	Composite	1	2	2	0	0	0	1
11	Last run, sweet	5	1	0	1	0	0	0
13	Green mold	1	0	0	0	0	0	0
Totals.....		28	11	12	4	1	0	6

Assuming that standard maintenance in two instances and a very close approach thereto in the third would suffice to pass a sample, a large share of the samples heretofore listed as below standard are eliminated and attention is fixed upon the 11 lots, listed in the last four columns, four of which are below in both total and insoluble ash, one low in both total ash and malic acid value, while six are low in all three items.

The following table has been prepared as an aid in locating the samples that show these deficiencies. The sample numbers correspond to those hitherto employed pages 352 to 390, reference to which will enable anyone interested to ascertain the entire history and chemical analysis of each lot.

TABLE 39. DEFICIENCIES GROUPED ACCORDING TO SAMPLE NUMBERS

Group number	Character of organism	Low in total ash	Low in Insoluble ash	Low in malic acid value	Low in total and insoluble ash	Low in total ash and malic acid value	Low in Insoluble ash and malic acid value	Low in total ash, insoluble ash and malic acid value
1 Control,	{	27, 28, 68 89, 97, 113	27 ..	.. ..	27 ..	.. ..	.. ..	.. ..
2 Incubator control,	{	96, 104, 112, 120	104, 112	112	104	.. ..	.. ..	112 107
4 Pink cocci		107	107	107	..	.. ..	.. ..	107
5 Failures,		106, 108	106, 108	31, 106, 108	..	.. ..	.. ..	108, 106
6 Red yeasts,		114, 99	114	114	.. ..	.. ..	.. ..	114
7 Gray yeasts,		110, 115	115	..	115	.. ..	.. ..	..
8 Fluorescent bacteria,	{	103, 101 91, 94		101, 102 100, 93	.. ..	101	.. ..	.. ..
9 Composite,		119	119, 116	119, 118	.. ..	.. ..	.. ..	119
11 Last run, sweet,	{	24, 122, 124 128, 129	124 ..	.. ..	124 ..	.. ..	.. ..	.. ..
Green molds,		117	..	..	..	.. ..	.. ..	.. ..

Examining closely into the deficiencies of the 11 samples previously mentioned, it appears that Nos. 27, 104, 115 and 124 were more concentrated than the standard requires; yet, the deficiencies in total ash are but 0.02, 0.08, 0.05 and 0.03% respectively. In three cases the insoluble ash is but 0.01% and in the other but 0.02% below. They equal or exceed the standard in malic acid value.

No. 101 contains 28.36% water and is 0.06% low in total ash and 0.07% low in malic acid value, while, on the other hand, it is 0.04% over standard in insoluble ash. The remaining six samples Nos. 112, 107, 106, 108, 114, and 119, fall short in all

three items, the total ash ranging from 0.06% to 0.13%, the insoluble ash from 0.01% to 0.03% and malic acid value from 0.01% to 0.16% below standard requirements.

Explanatory of the deficiencies enumerated above, attention is now called to a procedure that was employed on 11 of the samples reported in table 36, in which are listed the samples below standard in any particular, and which, fortunately, included 5 of those now being considered. These 11 samples were selected at random before the previous compilations had been made and their choice, at that time, depended on the size of the sample available, together with the concentration as indicated by the moisture content.

The treatment to which they were submitted is known as the "boiling and filtering process" first suggested by the writer in 1905.¹ This, as was then pointed out, is an important procedure in the certain determination of the purity of a maple product. Suitable portions of water were added and the samples containing both sirup and precipitated "niter" were mixed, heated in a water bath at 65 to 75° C. for an hour, and allowed to settle for two days. A portion was then decanted and boiled in a beaker, until a thermometer inserted in the sirup indicated 104° C. The sirup was immediately filtered hot through double filter papers and the ash and malic acid value determined on the clear filtrate. The results obtained by this procedure are given in the following table together with those originally secured on the concentrated and clarified samples.

¹ Vt. Sta. Rpt. 18, p. 328 (1905).

TABLE 40. EFFECT OF DILUTING, BOILING AND FILTERING ON CONCENTRATED MAPLE SIRUP COMPARED WITH THE ORIGINAL ANALYSES OF THE SAME SAMPLES

			CALCULATED TO A MOISTURE-FREE BASIS						
Character of organism	Sample number	Treatment	Moisture	Ash	Soluble ash	Insoluble ash	ALKALINITY		Malic acid value
							Soluble ash	Insoluble ash	
Control,	105	B. & F. *	%	%	%	%			%
"	"	Original	39.21	0.81	0.53	0.28	62	65	0.63
"	113	B. & F.	30.53	0.79	0.54	0.25	58	48	0.61
"	"	Original	37.25	0.96	0.55	0.41	64	51	0.75
In. control,	104	B. & F.	29.99	0.75	0.50	0.25	62	58	0.73
"	"	Original	35.40	0.77	0.43	0.34	62	59	0.74
Pink cocci,	107	B. & F.	29.46	0.69	0.47	0.22	62	42	0.60
"	"	Original	35.05	0.79	0.54	0.25	52	55	0.61
Failures,	108	B. & F.	27.90	0.71	0.50	0.21	57	34	0.58
"	"	Original	33.27	0.75	0.52	0.23	54	42	0.52
Red yeasts,	114	B. & F.	29.64	0.65	0.45	0.20	58	37	0.49
"	"	Original	35.75	0.92	0.65	0.27	58	53	0.62
Gray yeasts,	110	B. & F.	30.69	0.71	0.49	0.22	61	52	0.56
"	"	Original	35.62	0.81	0.56	0.25	56	59	0.61
"	115	B. & F.	30.94	0.67	0.44	0.23	58	52	0.65
"	"	Original	38.00	0.87	0.61	0.26	65	58	0.60
Fluo. bac.,	91	B. & F.	31.04	0.72	0.51	0.21	61	53	0.62
"	"	Original	35.95	0.78	0.51	0.27	59	59	0.61
Gr. molds,	111	B. & F.	26.75	0.72	0.44	0.28	58	58	0.90
"	"	Original	39.40	0.86	0.60	0.26	59	74	0.66
"	117	B. & F.	28.29	0.77	0.53	0.24	61	57	0.67
"	"	Original	35.75	0.87	0.53	0.34	62	65	0.64
"	"	Original	30.70	0.74	0.51	0.23	64	52	0.61

*Boiled and filtered.

The table shows conclusively that by simply diluting and boiling the entire sirup, including its niter, to its normal density, standards are met in every case. All the samples thus treated show an increased total ash content, sufficient to enable them to meet the standard requirement, save in the case of No. 108, the moisture content of which when boiled and filtered, was only 33.27%. The insoluble ash percentage has been increased in every case sufficient to fully meet the standard.

This treatment resulted in an increase in total ash for the 11 samples of 1.27%, averaging 0.115% for each sample, with extremes from 0.02 to 0.21%. The insoluble ash was increased 0.62%, averaging 0.056%, with extremes from -0.01 to +0.16%. The soluble ash was increased 0.55%, averaging 0.05%, with extremes from -0.04 to +0.16%. The standard is met as far as the malic acid value is concerned in all but one sample (No. 108) and even in this case the deficiency is slight.

This procedure seems to make it clear that the failure of several samples under discussion to meet standard requirements in certain particulars is not due to the influence of the inoculating organism employed, but rather to the over-concentration of the sample which, during the long period of sedimentation, caused a larger amount of niter to form and to settle out than would have formed and settled had the concentration been less and nearer that of the eleven-pound gallon.

SUMMARY

1. All inoculating organisms used (with a single exception, sirup number 12) had previously been obtained from maple sap and the so-called natural infection due to careless methods of gathering and handling may result in the introduction of any or all of the organisms employed in this investigation, with similar results as regards quality of product.

2. The conditions are more favorable to bacterial, yeast and mold contamination in the sap toward the close of the sugar season than earlier because of the higher temperatures, bare ground, rain, interrupted runs, less cleanly utensils, etc., which then obtain.

3. The relation of cleanliness in all operations and of promptness in collecting and boiling the sap to the maintenance of a high quality of product are strikingly shown by the results secured in this investigation.

4. The several forms of micro-organisms used in this study exerted apparently little or no effect on the ash content or the malic acid value of the sirups.

5. Slightly low ash contents and malic acid values were often obtained on individual samples of the better grades of sirup, which, however, represented the product from but a few trees. They occurred mainly when increased concentration beyond the eleven-pound gallon standard was followed by a prolonged sedimentation or thorough clarification.

6. The deficiencies noted in ash contents or malic acid values are not extreme and are due wholly to exceptional conditions of manufacture which would not obtain in commercial practice.

7. Standard maple syrup should weigh 11 pounds to the gallon, should carry between 34 and 35% of water, should give a Baumé reading of $35\frac{1}{2}$ to 36 at 60° F., and should contain, calculated to a moisture-free basis, a total (maple syrup) ash of 0.77%, an insoluble ash of 0.23% and a malic acid value of

0.60%. These figures constitute the standard now in use for determining purity. They are none too low, should be considered collectively, and, when properly interpreted, should enable certain differentiation between pure and adulterated maple products.

PART III

TECHNICAL DESCRIPTION OF CERTAIN BACTERIA OCCURRING
IN MAPLE SAP

By H. A. EDSON and C. W. CARPENTER

(A.) DESCRIPTION OF BACILLUS ACERIS
(NEW SPECIES)

SUMMARY OF CHARACTERS

I. OCCURRENCE AND CHARACTER

The bacillus occurs as the causal organism in a certain type of stringy maple sap, in which it produces an acid reaction and milky appearance. It seriously affects the clearness and flavor of sirup and also causes an increase in the content of invert sugar.

II. MORPHOLOGY

1. *Form*.—A bacillus, with rounded ends, occurring singly or in chains.

2. *Size*.—.9 to 1 micron by 1.5 to 3 microns.

3. *Agar hanging block*.—Organisms occur as single rods or in long chains according to the amount of moisture present. Orientation of chains either parallel or irregular.

4. *Endospores*.—Not found.

5. *Motility*.—Very actively motile in liquid media and frequently also on solid media. Two to 7 peritrichiate flagella readily demonstrated by either Löwit's, Loeffler's or the Pitfield method.

6. *Capsule*.—Slight capsulation when grown in maple sap, milk or on certain carbohydrate agars.

7. *Involution forms*.—Vacuolation occasionally observed on potato.

8. *Staining reactions*.—Organisms stained readily with 1-10 watery fuchsin, gentian violet, carbol fuchsin, and Loeffler's alkaline methylene blue. Not stained by Gram's method.

III. CULTURAL FEATURES

1. *Agar*.

Stroke.—Moderate, filiform to echinulate.

Stab.—Filiform, becoming villous or plumose, surface growth abundant, often spreading

Plate.—Colonies round or slightly irregular, smooth becoming radiate or striate, convex, edge entire, undulate or lobate; internal structure granular to grumose.

2. *Gelatin*.

Stab.—Beaded, becoming villous and plumose. Liquefaction napiform, becoming infundibuliform, beginning in 18 days, complete in from 60 to 80 days.

Plate.—Colonies round or irregular, convex, edge entire, undulate or lobate, liquefaction absent.

3. *Nutrient broth*.—Strong transient clouding with pellicle formation. Sediment flaky or membranous, later viscid on agitation.

4. *Cooked potato*.—Moderate persistent growth, echinulate or spreading below, convex, glistening, contoured, slimy to butyrous. Odor of alcohol. Medium grayed.

5. *Milk*.—Acid, coagulation delayed, beginning in from 4 to 6 days. Coagulum not peptonized. Litmus milk first red-dened, then reduced.

6. *Starch jelly*.—Growth copious, diastasic action feeble or absent. Reducing sugars not found, but alcohol formed.

7. *Silicate jelly containing Fermi's solution*.—Scanty growth.

8. *Cohn's solution*.—No growth.

9. *Uschinsky solution*.—Growth copious, the fluid becoming pronouncedly viscid.

10. *Sodium chlorid in bouillon*.—Growth in concentrations up to and including 9%, but not in 10%.

11. *Bouillon over chloroform*.—Growth unrestricted.

12. *Nitrogen*.—Obtained from peptone and asparagin.

IV. PHYSICAL AND BIOCHEMICAL FEATURES

1. *Gas production*.—Gas production in maple sap and in bouillon containing dextrose, sucrose, lactose, maltose, mannit, and potato extract, but not in bouillon containing glycerin. Gas composed of carbon dioxid and hydrogen.

2. *Growth in closed arm*.—Occurred in fermentation tubes of bouillon containing dextrose, sucrose, lactose, maltose, and mannit, and in tubes of potato extract, but not in tubes of bouillon containing glycerin.

3. *Acid production*.—Acid formed in maple sap, and in bouillon containing dextrose, sucrose, lactose, maltose, glycerin and mannit.

4. *Ammonia production*.—Moderate in bouillon.

5. *Nitrate reduction*.—Nitrates reduced to nitrites.

6. *Indol and phenol production*.—Feeble to moderate indol production in bouillon and in Dunham's solution. Phenol production negative.

7. *Toleration of acids*.—Medium growth in bouillon acidified with HCl to +25 Fuller's scale and in bouillon acidified to +20 with acetic acid.

8. *Toleration of sodium hydroxid*.—No growth in tubes of bouillon having a reaction more alkaline than —5 Fuller's scale. The organism was not killed in tubes having an initial reaction of —25, since, after twelve days, when the alkali was neutralized by atmospheric carbon dioxid, fair growth developed in such tubes. A more alkaline initial reaction invariably killed the organism.

9. *Optimum reaction*.—For growth in bouillon the optimum reaction was found to be +10 Fuller's scale.

10. *Vitality on culture media*.—Transfers from old cultures on various media, even when these had dried down, developed promptly.

11. *Temperature relations*.—Thermal death point in bouillon (10 minutes' exposure in water bath in thin walled tubes)

approximately 50° C. Optimum temperature 25° C. Maximum temperature 37° C. Minimum temperature not determined. Growth slow at 10° C.

12. *Desiccation*.—Growth occurred after drying for nine days in some cases, but not after drying for 20 days.

13. *Insolation*.—Exposure on ice to direct sunlight at noon in August for fifteen minutes killed 46.7% of the organisms.

14. *Acids produced*.—Not identified.

15. *Alkalies produced*.—Ammonia.

16. *Alcohols produced*.—Ethyl alcohol.

17. *Ferments produced*.—The organism digests gelatin slowly; yet notwithstanding all attempts to demonstrate proteolytic ferments by the milk serum method gave negative results. Potato starch was evidently acted upon feebly, alcohol being produced, but diastatic ferments could not be demonstrated. Invertase formed in very small quantities.

18. *Effect of germicides*.—Formalin and phenol were tested in varying amounts in bouillon. Phenol retarded growth in dilutions of 1-1000 and killed the bacillus in dilutions of 1-500. Formalin retarded growth in dilutions of 1-2750 and inhibited growth in dilutions of 1-2200.

19. *Number*.—According to the numerical classification of the Descriptive Chart of the Society of American Bacteriologists the organism is *Bacillus* 221.III3022.

DETAILED DESCRIPTION

OCCURRENCE

At various times during the progress of the study of the bacteria of maple sap, stringy or ropy specimens of the material were encountered. These were of two types. The more common form was usually observed only after the close of the commercial season and was associated with the presence of filamentous fungi, yeasts, and various bacteria growing together. This sap always presented a more or less lumpy appearance when poured from the bucket. The other type of stringy sap was of a more uniform

consistency and was found only a few times during the progress of the studies.

Such a specimen of sap was first received in the laboratory during the sugar season of 1908. It possessed a decidedly stringy character, being so ropy that after turning a little of it from the flask in which it was received the material continued to siphon from the container, even when its mouth was turned up so as to be somewhat above the level of the sap within. The material was uniform in consistency, milky in color, and possessed a pronounced yeasty odor. Examination under the microscope revealed enormous numbers of actively motile bacteria apparently in almost pure culture. When plates were poured almost all the colonies developing were of one type. Cultures obtained from these were found capable of reproducing the characters of the original material when introduced into fresh maple sap. As explained under the head "Cultural Characters," page 493, the stringy property developed to a pronounced degree only in unsterilized sap, but since it always appeared after inoculation with this organism, and only when this organism was employed, and since the bacillus was always recovered from the inoculated material in practically pure cultures, there can be no doubt of its causal relation to the condition of the sap.

The organism has a very detrimental influence upon the quality of sirup. While the color is not always seriously impaired the sirup is made more or less cloudy, a very unnatural and unpleasant flavor is developed, and the amount of invert sugar is increased by the action of the organism.

FORM

The organism is a bacillus with rounded ends, occurring singly, in pairs, or often in filaments in young agar or nutrient broth cultures at 20-25° C. Short chains (5 to 7 segments) often occur in cultures 24 hours old and chains of 20 or more segments are not infrequent. The tendency to chain formation is less pronounced in the older cultures and persists longer upon solid media than in liquid cultures.

MORPHOLOGICAL CHARACTERS

DIMENSIONS

Stained specimens for measurement were prepared from young (24 hour) agar and broth cultures with watery solutions of the common anilin stains, with anilin water gentian violet, and with carbol fuchsin. Measurements using a Zeiss homogenous 1-12 objective and a number 3 micrometer ocular, or by photography, showed a diameter of from .9 micron to 1 micron, the majority being slightly less than 1 micron. The length varied from 1.5 microns to 3 microns. Living organisms upon agar hanging blocks measured by either method were found to have the same dimensions as the stained organisms with the possible exception of a few instances, in which there was an apparent length of 5 to 6 microns. Since careful focusing in some of these cases revealed indistinct lines of fission it is possible that the longer bodies are really filaments of 2 or more segments. (See Plate VIII, figs. 9 and 10).

CULTURES ON AGAR HANGING BLOCKS

Agar hanging block cultures were prepared from small blocks of nutrient agar cut from poured plates and placed on sterile cover glasses, the surface next to the cover glasses being first touched with a dilution from a young nutrient broth culture. The cover glasses were placed on hollow ground slides and sealed either with vaseline or with a bit of melted agar to prevent evaporation, and the preparation held at room temperature (20-24° C.) for observation under the microscope. In abundant moisture the grouping was similar to that described on page 479 under the heading "Form." In cultures too dry to afford easy locomotion, but not dry enough altogether to inhibit motion, long, variously oriented, vibrating or squirming chains were observed. (See Plate VIII, figure 8, in which the motion of the chains gave the negative a badly blurred appearance). Blocks in which motility was prevented by lack of moisture developed chains of from 2 to many segments, the elements usually showing parallel orientation but sometimes developing an irregular grouping.

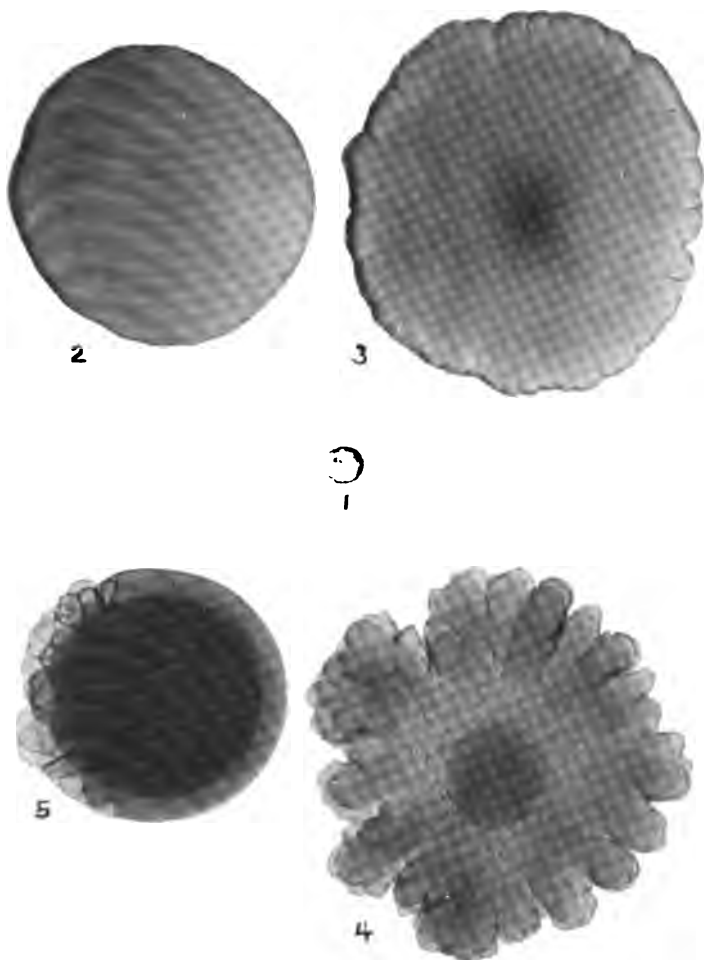


PLATE IX.—Gelatin colonies of *Bacillus aceris*. Figures 1, 2, 3, and 4. Photograph of the same colony one, two, four, and seven days old. Figure 5. Colony seven days old, showing transition stage from entire to lobate edge. (See page 487.) $\times 75$.

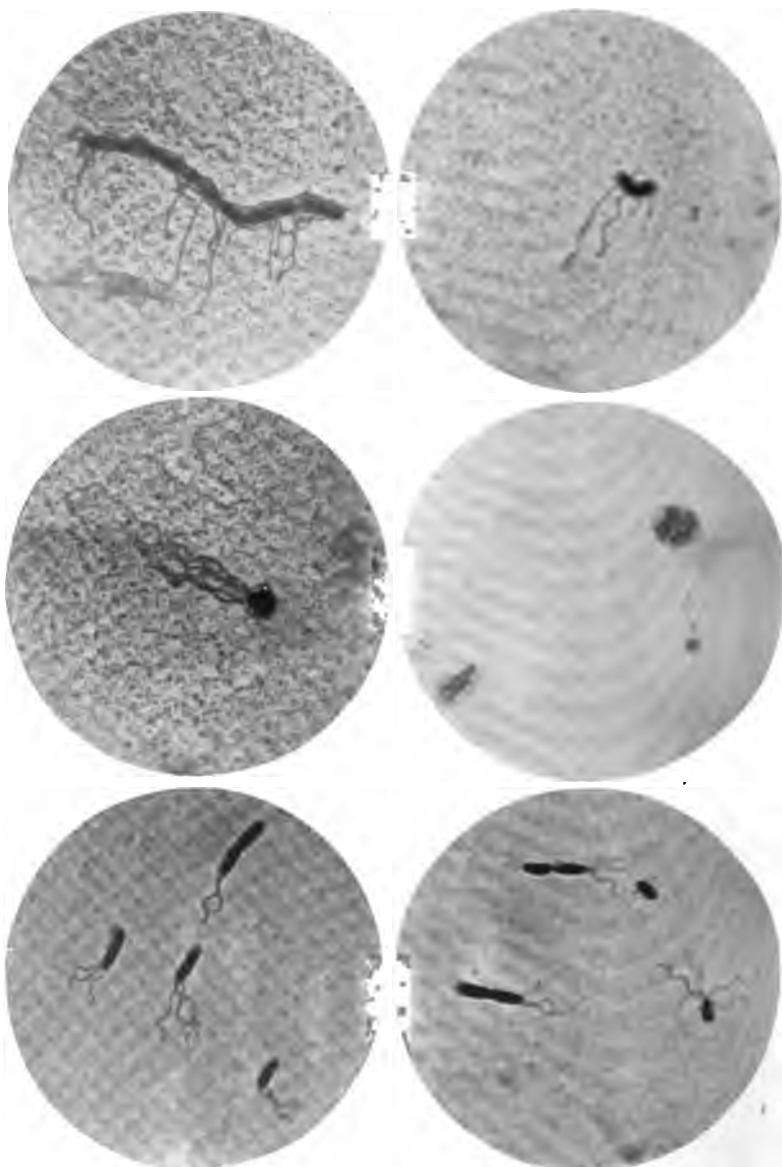


PLATE X.—Flagella preparations from 24-hour agar slants (Loeffler's stain). Figs. 1-4 show capsulation.

Fig. 1. *B. aceris*

Fig. 2. *B. parallelus*

Fig. 3. *B. parallelus*

Fig. 4. *B. parallelus*

Fig. 5. *Ps. fluorescens*,
strain CXLV

Fig. 6. *Ps. fluorescens*,
strain CXLV

(See pages 483, 554-556.) × 1500.

FISSION

The first indication of fission observed was a slight constriction at the center of organisms which were then 3 microns in length. The constrictions became gradually more pronounced and in the course of a few minutes two daughter cells each 1.5 microns in length were produced. These sometimes remained attached indefinitely while in other cases they separated almost at once. In the specimens observed the daughter cells showed no increase in length for a period varying from 20 minutes to 2 hours after division. There then occurred a period of rapid growth followed immediately by fission. The process of elongation and division were observed to take place in periods of from 20 to 40 minutes. Fission was completed in from 5 to 8 minutes after the first indication of its occurrence was observed. The active motility of this organism in abundant moisture made it impossible to carry out these studies under conditions of optimum humidity. The colonies under observation were so dry that growth continued only a few generations, and it is fair to assume that the rate of growth observed is far below the maximum. (Plate VIII, figures 1 to 5).

GROUPING

The formation of chains and filaments has been noted. Pseudo-zoogloea masses were observed in young cultures on broth, maple sap, and other liquid media.

MOTILITY AND FLAGELLA

Active motility occurred in young cultures in all liquid media employed. Colonies upon freshly poured plates of agar and gelatin exhibited internal motility under a Zeiss A objective and number 4 ocular. Motility became less marked in older cultures but was seldom entirely absent even in preparations made from cultures several weeks old, whether from liquid or from solid media. Flagella stains were obtained by Löwit's, Loeffler's, and the Pitfield methods, in preparations made from diluted condensation water of 24-hour old agar slant cultures. These

showed each rod to have from 2 to 7 peritrichiate flagella frequently developing a length of 15 microns. (Plate VIII, figure 6).

SPORES

No indications of spores were observed although search was made both by microscopic methods and by means of thermal death point determinations in old cultures upon agar and upon cooked potato.

CAPSULE

Microscopic examination of the mucilaginous deposit found in cultures upon maple sap as described under "Cultural Characters" revealed an envelope of almost transparent material and about 1 micron in thickness covering the organism. In unstained preparations, it was most readily observed by first placing the organisms in perfect focus with the diaphragm slightly open, and then reducing the light, when the colorless envelope became faintly though distinctly visible, presenting a well defined periphery. Organisms from the surface growth of carbohydrate agars showed a similar capsulation when mounted without the use of water. Organisms from carbohydrate agar condensation water or from milk showed a similar phenomenon, but the envelope was less clearly defined and scarcely more than .5 micron in thickness. Stained preparations from maple sap and milk cultures were disappointing. Sap preparations left to dry in the air formed a gelatinous mass about one-half the size of the original drop of culture placed on the cover slip, and the volume of this material could not be further reduced in drying with heat without charring the preparation. Richard Muir's capsule stain was tried repeatedly upon these preparations, but washing in water after the first mordant almost instantly dissolved the gelatinous mass and left the cover slips without a film of organisms. This difficulty was partially obviated by fixing in glacial acetic acid before the mordant and substituting a 2% salt solution for water in the subsequent washing. The stain, carbol fuchsin, was inactive

upon the material even when used with heat for 20 to 30 minutes, while the blue counter stain acted upon the organisms faintly. Part of the bacilli on the films thus treated showed an unstained envelope lighter than either the body of the organism or the field and from .5 to .75 micron in diameter. When Welch's capsule stain was employed the organisms from sap cultures appeared distinctly stained, surrounded by a transparent envelope .75 to 1 micron in thickness. Films from carbohydrate agar prepared by Welch's method showed a colorless envelope upon practically all organisms. Flagella preparations from 24 hour agar slants stained by Loeffler's method with anilin gentian violet often exhibited the capsule clearly stained. (Plate X, figure 1).

INVOLUTION FORMS

In a few cases oval refractive bodies suggestive of spores were seen in preparations from cooked potato cultures several weeks old. Transfers taken from such cultures were invariably killed by heating for 10 minutes at 55° C. and attempts to stain the bodies by the usual methods for spores gave negative results. These bodies were deemed to be vacuoles.

STAINING REACTIONS

Preparations made from 24 hour old cultures upon nutrient broth and nutrient agar were readily and deeply stained by cold watery solutions of the anilin dyes, by Ehrlich's anilin water gentian violet and by carbol fuchsin. Many of the rods stained by carbol fuchsin exhibited plasmolysis. It is an interesting fact that organisms from broth and agar cultures were deeply stained by exposure for 10 seconds to cold carbol fuchsin, while this stain used either cold or hot was totally ineffective with Richard Muir's method of capsule staining applied to organisms from sap cultures, as reported under the head "capsule." The organism was decolorized by the method of Gram.

CULTURAL CHARACTERS

METHODS

The culture media employed in this work were carefully prepared following closely the directions given in Smith's "Bacteria in Relation to Plant Diseases" and the publications of the American Public Health Association. Distilled water of a high degree of purity was used unless otherwise stated. The formula employed for preparing nutrient broth was 10 grams Witte's peptone, 5 grams of Liebig's extract of beef, and one liter of distilled water. Sodium chlorid was used only when so stated. All agar media contained 1.5% of agar flour. The reaction of media containing nutrient broth was +10 Fuller's scale unless otherwise noted. Titrations were made upon 5 cc. of medium diluted with distilled water to 50 cc. The reaction was determined in hot solution with N/20 sodium hydroxid against phenolphthalein. All transfers except those for determining spore formation were made from broth cultures 1 to 3 days old or from dilutions of the same in water or, for some special purposes, in liquid culture media. Transfers to fluid media were made with a 2 mm. platinum-iridium loop, and those to solid media with a straight needle. Exceptions are noted in special cases as they occur.

Agar stroke.—Cultures developed good growth within 24 hours, which was moderate in amount, varying from a filiform line to an echinulately bordered, rather broad band. The elevation varied from raised to broadly umbilicate, with a surface at first smooth but becoming faintly papillate and contoured in 4 or 5 days. Cultures 2 weeks or more old showed long villous or sometimes fleecy outgrowths into the substratum. The growth was translucent, accompanied by slight opalescence and a glistening luster. The culture was of slimy or butyrous consistency without definite color, developing no discoloration of the medium. The tubes gave off a mild yeasty odor.

Agar stab.—Young stab cultures in agar showed a growth which at first was uniform along the line of puncture, later be-

coming better developed at the top, with a moderately spreading surface growth. Development along the line of puncture was at first filiform and then echinulate. Cultures 10 days old or more were often beset with scattered tufts of villous or plumose out-growths usually more pronounced in the upper part of the medium.

Agar plates.—Colonies at 25° C. showed rapid growth. Those at the surface were at first round, sometimes becoming slightly irregular. In the early stages the surface was smooth, often becoming contoured and papillate or developing moderate striations and concentric markings. These characters were not infrequently combined in the same colony. The elevation was convex. The edge was at first entire or undulate, frequently becoming lobate. The internal structure of surface colonies showed all stages of variation from finely granular through coarsely granular to grumose and, less frequently, reticulated. The outer portion of many colonies was filamentous or curled. Young cultures often showed an even outer ring well differentiated from the body of the colony and consisting of motile chains through which were thickly scattered granules. The appearance suggested that which is often seen in very early stages of liquefaction on gelatin plates, but there was no sign of liquefaction in the agar. Young surface agar colonies 1 to 3 days old usually showed active motility within the colony. Buried colonies first appeared as brown lenticular bodies, often becoming irregular with the interior deeply reticulated.

Carbohydrate agars.—Cultures were made in shaken agar tubes containing 2% lactose, dextrose and sucrose, respectively. Just previous to sterilization 1% of a solution of azolitmin (one gram of azolitmin to 16 cc. of distilled water) was added to the tubes. The sterilized melted agar was cooled to 40° C., inoculated with a 2 mm. loop of a 24 hour old culture, thoroughly mixed by shaking and incubated at 25° C.

In lactose litmus agar good growth developed and acid production became evident during the first day. A heavy white film

of surface growth developed and during the third day gas production began. This continued to increase in amount for a few days and then ceased. The reaction remained acid and at no time was there evidence of reduction of the litmus.

In dextrose litmus agar the growth was more rapid than in agar containing lactose. The acid production was more pronounced and the gas formation observed was greater than was the case with either lactose or sucrose. Signs of bleaching at the surface appeared on the fifth day and progressed rapidly till the entire contents of the tube assumed a pale yellowish hue. The formation of a layer of liquid above the surface film of growth was noted in most of the tubes under observation.

In sucrose litmus agar tubes the organism developed very much as in dextrose tubes except that the growth and the various characters were slightly less pronounced, or at best developed a little later.

Gelatin.—All gelatin media contained 10% of Nelson's photographic gelatin No. 1 and was of such a consistency as to remain firm at 25° C. Gelatin cultures were incubated at 20° C.

Gelatin stroke.—Gelatin slants showed a beaded growth along the line of inoculation, frequently becoming filiform or echinulate, sometimes developing into a broad band with roundly dentate margins and spreading beneath into an arborescent growth. After a few days a fine filamentous outgrowth developed beneath the surface under the stroke and extended several mm. into the body of the gelatin. In some series this growth finally became arborescent while in others this character failed to develop to an appreciable extent. Liquefaction of gelatin began on the eighteenth day, and proceeded very slowly thereafter, becoming complete in about three months.

Gelatin stab.—Stab cultures in gelatin showed best growth at the top. The line of puncture was beaded, the beads soon united to form a granulose mass with a villous border developing into long capillary fibers extending nearly to the walls of the tube. These fibers eventually developed fine lateral branches.

thus producing a cloudy appearance. A characteristic surface colony was formed. The medium remained unchanged until the eighteenth to twentieth day when the first signs of liquefaction were observed. The action was very feeble but persistent. Tubes were completely liquefied in from 60 to 80 days. The cultures 30 days old exhibited infundibuliform or slightly napiform areas of liquefaction extending from the surface down about 15 mm. A heavy sediment deposited at the base of the liquefied portion which was clear above and covered by a firm, dry layer which had to be broken with a needle or by violent shaking in order to allow the liquefied portion to run out when the tube was inverted.

Gelatin colonies.—Growth upon gelatin plates developed rapidly at 20° C., producing colonies at first round and finally becoming deeply lobed under favorable moisture conditions. The elevation of growth was convex. During the early stages the colonies presented an entire edge becoming undulate the second day, and thereafter gradually becoming deeply lobate. The internal structure was at first finely granular becoming deeply reticulate or alveolar and developing a great variety of markings during the transition. Colonies one week old were strikingly characteristic, having a dark alveolar center surrounded by an intermediate lighter zone bearing finely reticulate markings, and verging into the outer zone consisting of deeply cut compact lobes composed of conglomerate aggregates, as if they had been formed by repeated expanding, bursting and reforming of an enveloping pseudomembrane. Liquefaction was not observed upon gelatin plates. (Plate IX).

Broth.—Cultures showed rapid growth and became semi-opaque from clouding in 24 hours at 25° C. The clouding increased for several days and was accompanied by the formation of a flaky or somewhat membranous pellicle. The sediment at first viscid became flaky in from 2 to 5 days. Cultures 6 to 8 weeks old were free from clouding with no pellicle but contained a sediment which was viscid on agitation. The broth at this age

took on a dark rich amber color and reacted distinctly alkaline to litmus.

Potato blocks.—Cultures upon cooked potato blocks showed a persistent growth which was moderate in amount, echinulate, often spreading at the base; convex with a glistening luster, contoured surface, and slimy to butyrous consistency. The tubes gave off a characteristic odor suggestive of alcohol, and gas production was noted. The medium was grayed.

Milk.—Tubes of fresh centrifuged milk inoculated with a 2 mm. loop of 24 to 48 hour old broth cultures held at 25° C. showed no visible change for 4 to 6 days. Thereafter coagulation occurred with gradual shrinking of the curd and extrusion of whey, accompanied by gas formation. The same changes were observed both at 20 and at 30° C., but the process was always slower at the lower temperature and more rapid at the higher. The coagulum was firm and leathery, becoming slightly yellowish by reflected light. Tubes held under observation for 2 months showed yellowish translucent spots which suggested slight peptonization, but they were believed to result merely from shrinking of the curd. (See production of proteolytic enzymes, pages 509).

Acid production in milk.—This was determined in the following manner: Freshly drawn milk was centrifuged, then further freed from fat by filtering through several thicknesses of filter paper, carefully pipetted into tubes, 10 cc. in a tube, sterilized by discontinuous steaming on 3 consecutive days, and inoculated with a 2 mm. loop from young broth cultures. Titrations were made at the end of 1, 2, 4, 10, and 20 days, respectively. For this purpose the content of the tube was added to 40 cc. of distilled water, the mixture boiled for 1 minute and at once titrated against phenolphthalein with N/20 sodium hydroxid. The acid production was calculated by subtracting from the reaction of the inoculated tube the average reaction of all check tubes in the same series and averaging the differences thus obtained.

TABLE 41. ACID PRODUCTION IN MILK

Age of culture	Series 1, 20° C.			Series 2, 20° C.		
	Reaction in Fuller's scale		Acid production in cc. N/1 per liter	Reaction in Fuller's scale		Acid production in cc. N/1 per liter
	inoculated tubes	control		inoculated tubes	control	
1 day,	19.7	12.0		15.0	14.6	3.0
1 day,	19.2		7.3	18.2		
2 days,	28.3	9.9		25.0	13.3	10.7
2 days,	25.6	12.5	14.6	23.6		
4 days,	39.4	12.4		26.7	13.2	13.7
4 days,	33.6	10.1	24.2	28.0		
10 days,	46.6	13.6		36.7	14.0	25.8
10 days,	39.6	15.0	30.9	42.1		
20 days,	49.1	11.4		lost		
20 days,	41.4	12.9	33.0	lost		
Average of controls,		12.20			13.6	
	Series 3, 25° C.			Series 4, 25° C.		
1 day,	28.8	17.8		27.5		
1 day,	27.8	17.8	9.6	27.8	18.4	8.5
2 days,	32.3	20.0		34.0		
2 days,	32.6	20.5	13.3	30.5	18.8	13.1
4 days,	32.0	19.5		37.8		
4 days,	32.0	19.8	12.8	38.3	20.0	18.9
10 days,	37.0	18.8		48.3		
10 days,	37.0	19.0	17.8	46.3	19.6	28.1
20 days,	48.3	19.0		54.5		
20 days,	46.8	19.4	28.4	52.0	19.2	34.1
Average of controls,		19.2			19.2	
	Series 5, 25° C.			Series 6, 25° C.		
1 day,	18.7	10.2		20.0	13.7	8.0
1 day,	18.4	8.8	8.4	22.7		
2 days,	27.1	9.1		28.0	12.5	13.7
2 days,	26.9	....	16.8	26.0		
4 days,	27.1	9.1		35.5	12.8	22.9
4 days,	27.1	8.5	16.9	37.0		
10 days,	39.9	12.1		40.0	14.2	28.4
10 days,	38.3	....	28.9	45.5		
20 days,	45.4	12.1		48.0		
20 days,	48.3	11.7	36.7	48.6	13.3	35.0
Average of controls,		10.2			13.3	

ACID PRODUCTION—*Continued*

Age of culture	Series 7, 25° C.			Series 8, 30° C.		
	Reaction in Fuller's scale		Acid production in cc. N/1 per liter	Reaction in Fuller's scale		Acid production in cc. N/1 per liter
	inoculated tubes	control		inoculated tubes	control	
1 day,	23.9	12.6	10.6	26.2	10.0	13.8
1 day,	21.2	10.6		25.3	....	
2 days,	29.1	10.9	14.0	28.6	12.2	18.8
2 days,	22.9	12.3		32.9	12.8	
4 days,	42.9	11.9	24.7	37.8	15.6	27.5
4 days,	30.4	12.7		41.1	10.6	
10 days,	46.6	12.2	33.9	48.5	13.8	31.9
10 days,	45.0	....		39.2	13.6	
20 days,	50.5	11.4	38.6	54.5	13.2	43.3
20 days,	....	12.9		56.0	15.9	
Average of controls,		11.93			11.94	

Series 9, 30° C.			
Age of culture	Reaction in Fuller's scale		Acid production in cc. N/1 per liter
	inoculated tubes	Controls	
1 day,	24.7	13.5	11.8
1 day,	26.2		
2 days,	33.5	13.0	21.1
2 days,	36.0		
4 days,	42.4	14.0	27.1
4 days,	39.0		
10 days,	44.0	14.2	30.7
10 days,	44.7		
20 days,	57.8	14.3	43.9
20 days,	58.6		
Average of controls,		13.8	

TABLE 42. AVERAGE ACID PRODUCTION IN MILK IN CC. N/1 PER LITER

	20° C.	25° C.	30° C.
1 day,	5.15	9.02	12.80
2 days,	12.65	14.18	19.95
4 days,	18.95	19.24	27.30
10 days,	28.35	27.42	31.30
20 days,	33.00	34.56	43.60

Litmus milk was prepared by adding 0.10% of azolitmin to fresh centrifuged milk and filtering through several thicknesses of filter paper. Acid production became apparent within 24 hours at 20, 25 and 30° C. followed by gas production, coagulation, and extrusion of the whey, as reported under milk. Gradual but complete reduction of the litmus was observed beginning at the top of the tube about the sixth day and becoming complete about the sixteenth day. No further change was observed in tubes held under observation for 3 months.

Starch jelly was prepared according to the directions given by Smith. The nutrient material employed was the same author's modification of Uschinsky solution. Good growth occurred upon this within 24 hours. A broad band of raised growth, higher at the border than at the center, with a papillate surface, an echinulate edge and a faint opalescence, resulted. Slight local liquefaction of the medium was noted on the sixth day accompanied by a change from opalescence to opaqueness with gas production in the medium. On the tenth day and at intervals thereafter for six weeks, tubes were examined by washing with distilled water. Portions of the starch jelly had been rendered soluble so that pockets were left in the surface. The wash-water and dissolved material was passed through filter paper and tested for sugar with Fehling's solution, with negative results. A portion of the filtrate was distilled and the distillate tested with sodium hydroxid and iodine as described under alcohol production. Iodoform was produced, indicating the presence of alcohol, aldehyde, or ketone. From the fact that Fehling's solution was not reduced the probability is strongly in favor of the supposition that the body was an alcohol.

Cohn's solution proved an unfavorable medium for the cultivation of this organism. Cultures held under observation for 21 days failed to show growth.

Uschinsky solution.—Cultures developed a copious growth appearing within 24 hours, accompanied by a pellicle formation which after about 3 days sank and deposited as a membranous

sediment. The medium was slightly viscid at the end of 2 weeks.

Fermi's solution inoculated with organisms developed a slight growth within 24 hours, followed by the formation of a thin pellicle which sank and formed a thin membranous sediment. The growth was transient, the tubes becoming almost clear in 3 days.

Silicate jelly containing Fermi's solution showed a light growth, becoming apparent the second or third day as a thin, pearly white, surface development. The medium and growth thereafter remained unchanged.

Sodium chlorid in bouillon.—Transfers were made to bouillon (+10 Fuller's scale) containing 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12%, respectively, of chemically pure sodium chlorid. Growth promptly appeared in the four weaker solutions, but was very slightly restricted in 5% sodium chlorid. It invariably appeared upon the 6% and 7% solutions within 4 days and upon the 8% and 9% ones in from 3 to 7 days. No growth occurred in 10%, 11%, or 12% sodium chlorid bouillon within 21 days. Transfers from these tubes into normal bouillon gave no growth. In no case was development entirely inhibited by less than 10% of sodium chlorid, but cultures in solutions containing from 5% to 9% were not characteristic. Microscopic examination showed organisms to be grouped together in chains in the 5% solution. No signs of motility were observed in this or stronger concentrations. In the broths containing in excess of 5% the growth was restricted to clustered colonies gathered on the sides of the tubes. In solutions up to 4% growth was apparently normal, the grouping and motility being characteristic.

Growth in bouillon over chloroform was unrestricted and characteristic.

Maple sap sterilized by heating at 99 to 100° C. on three consecutive days and inoculated with a 2 mm. loop of the organism, developed a deep milky appearance within 24 hours. Growth was accompanied by the formation of mucilaginous gum on the walls of the flask in contact with the culture fluid. This layer

increased in amount for one or two days, but began to diminish on the fourth day and was entirely gone on the sixth day. Meantime the milky appearance of the sap remained unchanged. A slimy consistency developed and the material sometimes became stringy, but the pronounced ropy character described under cultures in unsterilized sap did not appear.

Unsterilized sap was employed in a large number of the inoculation experiments. Care was taken to procure this fresh from the trees and as slightly contaminated as possible by bits of dust, bark, and other extraneous matter, in order that the natural inoculations should be minimized. In the first series a young culture in beef broth was employed for the inoculations, about 5 cc. of culture being added to a liter of sap; in other series varying small amounts of broth culture were employed, and in still others pure cultures upon sterilized sap were used to produce the inoculations. The cultural characters were invariably the same, except that the heavier inoculations produced the results more quickly. The sap took on a deep milky appearance but developed no pellicle. A slime was deposited upon the walls of the containing vessel but the gummy consistency of the deposit described under sterilized sap was not observed. Moreover the liquid developed a ropy character which was very pronounced after 24 to 48 hours and persisted for the two weeks that the cultures were held under observation. The character of the culture produced by inoculation with the organism after it had been cultivated in the laboratory for one year was exactly similar to that observed in the original material from which the organism was isolated. The maximum reaction observed in unsterilized sap in which this organism was cultivated for three days was $+17$ Fuller's scale. Before inoculation the reaction was $+3$. Associated organisms, when introduced in maple sap in such quantities as to cause an overgrowth, produce a reaction of $+6$ to $+1$.

Artificial maple sap was prepared from maple sirup as follows: 25 cc. of sirup, 475 cc. of water and 25 cc. of nutrient bouillon were mixed, heated to boiling, filtered through filter

paper and sterilized in flowing steam on each of three consecutive days. When inoculated this medium clouded promptly, becoming milky. Ten day old cultures were slightly opalescent and very milky, but neither pellicle nor sediment developed. The reaction as shown by titration against phenolphthalein was +.81 Fuller's scale. Fermentation tubes filled with this medium showed equally good growth in the open and closed arms, characterized by a deep milky appearance and moderate gas production. The material became viscid and sometimes a little stringy. From 5 to 15% of the closed arm was filled with gas consisting of carbon dioxid and hydrogen.

PHYSICAL AND BIOCHEMICAL FEATURES

Gas production in milk.—Fermentation tubes containing milk inoculated with a 2 mm. loop of a young culture of the organism and plated at 20° C. showed a small bubble of gas in the closed arm at the end of two days; otherwise the milk was unchanged in appearance. Held at 25° C., the tubes of the same age showed gas in 8% of the closed arm, while those held at 30° contained from 15 to 20%. On the third day at 20°, 5% had developed, at 25°, 15 to 20%, and at 30°, 40 to 45%. The appearance of the milk still remained unchanged. Cultures 10 days old showed varying amounts of gas up to 100% of the closed arm. The milk was coagulated and the firm coagulum usually remained in the closed arm attached to one side of the tube. About 70% of the gas produced was absorbed by sodium hydroxid and the remainder gave a slight explosion upon ignition in air.

Carbohydrate broth.—Fermentation tube cultures of nutrient bouillon containing dextrose, sucrose, lactose, maltose, glycerin, and mannit were observed for gas production and acid production. Titrations were made at the end of the first, second, and fourth days, using 5 cc. of the culture in 45 cc. of boiling water against phenolphthalein. Dextrose tubes showed rapid development of the organism. At 20° the tubes became cloudly through-

out within 15 hours after inoculation, while at 25 and 30° gas production was well under way. The growth in lactose and sucrose was similar to that in dextrose but less pronounced. Maltose was especially favorable for the development of the organism and abundant gas production was obtained upon this sugar. Glycerin broth appeared a good medium for growth in the open arm, but only restricted growth occurred in the closed arm, and no gas was produced. Mannit gave good growth in both the open and closed arms accompanied by gas production. The tables showing acid production follow.

TABLE 43. ACID PRODUCTION IN CARBOHYDRATE BROTH

Age of culture	Reaction in Fuller's scale					
	Acid production		Acid production		Acid production	
	Inoculated tubes	in cc. N/1 per liter	Inoculated tubes	in cc. N/1 per liter	Inoculated tubes	in cc. N/1 per liter
Series 1-3. Dextrose						
	At 20° C. ¹		At 25° C.		At 30° C.	
1 day,	14.0	4.0	17.0	7.0	20.0	10.0
1 day,	15.0	5.0	18.0	8.0	20.0	10.0
2 days,	21.2	11.2	23.0	13.0	22.5	12.5
2 days,	21.2	11.2	24.5	14.5	24.0	14.0
4 days,	19.5	9.5	21.5	11.5	15.3	5.3
4 days,	19.5	9.5	21.2	11.2	16.0	6.0
Series 4-6. Sucrose						
	At 20° C. ²		At 25° C.		At 30° C.	
1 day,	14.5	5.0	16.5	7.0	19.5	10.0
1 day,	14.5	5.0	17.0	7.5	19.5	10.0
2 days,	16.2	6.7	20.0	10.5	19.5	10.0
2 days,	17.2	7.7	19.0	9.5	10.3	10.8
4 days,	17.5	8.0	16.5	7.0	16.8	7.3
4 days,	18.5	9.0	16.5	7.0	17.7	8.2
Series 7-9. Lactose						
	At 20° C. ³		At 25° C.		At 30° C.	
1 day,	12.0	2.5	16.5	7.0	20.0	10.5
1 day,	11.0	1.5	17.5	8.0	20.0	10.5
2 days,	15.5	6.0	16.8	7.3	19.0	9.5
2 days,	15.5	6.0	16.7	7.2	18.0	8.5
4 days,	16.0	6.5	18.0	8.5	18.0	8.5
4 days,	17.0	7.5	19.0	9.5	18.5	9.0

¹ Average of controls, 10.0.² Average of controls, 9.5.³ Average of controls, 9.5.

TABLE 43—Continued

Age of culture	Reaction in Fuller's scale					
	Inocu- lated tubes	Acid production in cc. N/1 per liter	Inocu- lated tubes	Acid production in cc. N/1 per liter	Inocu- lated tubes	Acid production in cc. N/1 per liter
	Series 11-12. Maltose					
	At 20° C. ^a		At 25° C.		At 30° C.	
1 day,	14.2	2.8	18.3	6.9	17.5	6.1
1 day,	15.7	4.3	18.7	7.3	16.5	5.1
2 days,	16.2	4.8	16.5	5.1	18.0	6.6
2 days,	16.5	5.1	16.5	5.1	17.6	6.2
4 days,	19.6	8.2	18.9	7.5	18.2	6.8
4 days,	17.8	6.4	17.6	6.2	19.0	7.6
Series 13-15. Glycerin						
	At 20° C. ^a		At 25° C.		At 30° C.	
1 day,	9.0	—0.6	8.2	—1.4	9.7	0.1
1 day,	9.3	—0.3	8.5	—1.1	10.5	0.9
2 days,	11.2	1.6	10.3	0.7	10.9	1.3
2 days,	11.2	1.6	10.5	0.9	10.9	1.3
4 days,	11.0	1.4	11.1	1.5	13.7	4.1
4 days,	11.7	2.1	11.4	1.8	13.7	4.1
Series 16-18. Mannit						
	At 20° C. ^a		At 25° C.		At 30° C.	
1 day,	12.0	4.0	14.0	6.0	15.0	7.0
1 day,	14.0	6.0	12.8	4.8	15.1	7.1
2 days,	14.7	6.7	16.1	8.1	17.8	9.8
2 days,	15.3	7.3	15.7	7.7	16.0	8.0
4 days,	16.4	6.4	16.8	8.8	19.6	11.6
4 days,	17.0	9.0	17.9	9.9	20.2	12.2

^a Average of contents, 11.4.^b Average of controls, 9.6.^c Average of controls, 8.0.

The rate of gas production in the closed arms of the Smith tubes was followed by measuring with the Frost card. The amount of carbon dioxid formed was determined approximately by absorbing it within the tube with sodium hydroxid, the volume being noted before and after absorption. The residue was subjected to the flame test for hydrogen. A positive reaction invariably resulted, although the explosion was frequently so faint as to arouse suspicion that the material tested might be a mixture of gases rather than pure hydrogen. The tabulated results follow. The figures express the percents of the closed arm of Smith tubes which were filled with gas.

TABLE 44. GAS PRODUCTION IN CARBOHYDRATE BROTHS

Age	Temperature	Dextrose	Lactose	Sucrose
1 day,	20° C.	trace	0	0
	25° C.	5%	trace	5%
	30° C.	15%	8%	14%
2 days,	20° C.	15%	3%	8%
	25° C.	25%	20%	35%
	30° C.	40%	25%	35%
4 days,	20° C.	35%	25%	25%
	25° C.	45%	40%	30%
	30° C.	45%	48%	50%

TABLE 45. PROPORTION OF CARBON DIOXID TO TOTAL GAS

Series 1. Four days old						
	20° C.		25° C.		30° C.	
	Percent of gas produced	Percent CO ₂ to total	Percent of gas produced	Percent CO ₂ to total	Percent of gas produced	Percent CO ₂ to total
Dextrose,	35	43	45	44	45	55
Lactose,	25	20	40	30	48	35
Sucrose,	25	40	30	45	50	50
Series 2. Fourteen days old						
Dextrose,	29	62	56	50	48	45
Ditto,	39	59	63	44	45	57
Ditto,	40	60	51	58	..	..
Lactose,	37	75	48	58	36	72
Ditto,	40	72	35	63	41	61
Ditto,	40	70	55	60	31	77
Sucrose,	26	50	49	53	48	..
Ditto,	25	48	27	70	34	62
Ditto,	26	54	57	49	41	53

Fermentation tubes of nutrient broth containing 2% of mannit showed gas production in 24 hours at 25° C. but not at 20°. At the end of two days 10% of gas had developed at 20° while at 30° 25% had formed. Cultures six days old showed a development of about 40% of gas, approximately one-half of which was absorbed by sodium hydroxid. Evidences of fermentation of maltose at 20° were pronounced in 15 hours, progressing rapidly till 40 to 50% of gas was formed, which was similar in composition to that produced upon other sugars. No gas was produced upon glycerin broth.

Fermentation of potato starch.—Potato fermentation tubes were prepared by placing cylinders of potato in the closed arm and filling with distilled water. The tubes were sterilized by steaming on each of three consecutive days, and inoculated with a 2 mm. loop from young broth cultures. Gas production occurred within 15 hours after inoculation in tubes held at 30°. At the end of three days tubes kept at 20° showed 25 to 35 percent of the closed arm filled with gas. The gas was tested with sodium hydroxid and the flame test and found to contain carbon dioxid and hydrogen.

Potato extract was prepared by boiling potatoes one-half hour in distilled water and decanting the liquid upon a filter. Fermentation tubes of the medium developed good growth. Gas consisting of carbon dioxid and hydrogen was produced by the second day. Tests for reducing sugars and for aldehydes made on the third day negative results. These ingredients were sought by the Fehling solution and ammoniacal silver nitrate methods, respectively. Potato extract to which 4% of sucrose was added, developed a remarkable growth. The fluid became milky and slightly stringy and developed a yeasty odor very much like that produced in sap.

Gas production in modified Uschinsky solution containing carbohydrates.—To modified Uschinsky solution 2% of the following carbohydrates were added, maltose, dextrose, sucrose, lactose and mannit. The media were placed in fermentation

tubes, sterilized by flowing steam on each of three consecutive days, and inoculated in the usual way. At the end of 8 days gas production in the closed arm was as follows: Maltose 22%, dextrose 15%, sucrose 12%, lactose 5%, and mannit 14%. The composition of the gas was similar to that previously described. Gas production in maple sap and in starch jelly containing modified Uschinsky solution has been mentioned under cultural characters.

Ammonia production was determined in 100 cc. portions of nutrient broth in 500 cc. flasks inoculated with 1 cc. portions of young cultures and incubated at room temperatures, 20 to 23° C. Determinations were made at the end of 5, 10 and 12 days. For this purpose an excess of heavy magnesium oxid and 100 cc. of distilled water were added. The flask was connected with a Liebig condenser and distilled, the distillate being received in a flask containing a measured quantity of N/20 hydrochloric acid. The excess of acid was titrated against cochineal as an indicator and the ammonia production calculated. An equal volume of the same broth which had been kept under identical conditions was analyzed for ammonia at the same time. The results are recorded in the following table:

TABLE 46. AMMONIA PRODUCED IN NUTRIENT BROTH

Age	Inoculated	cc. N/20 HCl neutralized	Control		cc. N/20 NH ₃ produced per 100 cc. broth
5 days,	11.80	—	2.00	=	9.80
10 days,	36.20	—	4.20	=	32.00
12 days,	33.15	—	4.75	=	28.40
12 days,	28.25	—	4.25	=	24.00

Nitrate reduction.—Nitrate broth was prepared according to the following formula: One liter distilled water, 3 grams Liebig's extract of beef, 10 grams chemically pure potassium nitrate. The reaction was adjusted to zero with sodium hydroxid. The organism made vigorous growth upon this medium as exhibited by the prompt clouding and production of sediment. There was a marked tendency towards clearing in the upper

portion of the medium. Cultures were grown at 20, 25, and 30° C. and tested for nitrites at the end of 3, 5, 10 and 25 days with prompt and positive reaction. The test was made with the following solutions:

(1) One gram of potato starch boiled in 100 cc. of distilled water. (2) One-tenth gram of potassium iodid in 25 cc. of distilled water. (3) Two parts of chemically pure sulphuric acid and one part water. To the tubes to be tested 1 cc. of number 1, and 1 cc. of number 2, and, then, three drops of number 3 were added, the tubes being agitated after each addition.

Indol production.—The tests for indol production were made in Dunham's peptone solution and in sugar free bouillon. Both media were well suited to the growth of the organism. The test was made by adding 10 drops of chemically pure sulphuric acid (two parts sulphuric acid to one part water). After allowing the tubes to stand for 20 minutes to determine the absence of reducing bodies, 1 cc. of 0.02% sodium nitrite solution was added. Cultures 10 days old on Dunham's peptone solution gave a pink color in from 1 to 5 minutes after the addition of the nitrite. Cultures grown at 20° responded somewhat more slowly and with a fainter reaction than those which were held at higher temperatures. As a check upon the work, tubes of the same medium were inoculated with a strain of *B. coli* which produced indol vigorously, and held at 30° C. Taking the color obtained from these tubes as a standard, represented numerically by 10, cultures of the organism held at 30° produced a color of 5 within one minute. Cultures held at 20° produced a color of 1 after 15 or 20 minutes. A large number of cultures were tested in both Dunham's solution and in sugar free bouillon and positive, though sometimes faint, reaction was obtained in every case.

Production of phenol.—Tests for the production of phenol were made upon 50 cc. portions of 10 day old broth cultures of the organism. The material was transferred to a distilling flask, 5 cc. of concentrated hydrochloric acid added, and about 20 cc. of distillate collected. This was divided into three portions.

One was treated with a few drops of Millon's reagent,¹ another with two or three drops of dilute solution of ferric chlorid, and the third with a few drops of strong bromine water.² The results were negative.

The reaction for phenol is sometimes obscured by the presence of traces of indol. To eliminate this source of error 200 cc. cultures were distilled with 50 cc. of concentrated hydrochloric acid. The 70 cc. of distillate obtained was rendered alkaline with potassium hydroxid and again distilled. Indol should come over in the distillate while phenol remains in the residue. The residue was cooled, saturated with carbon dioxid and distilled. This final distillate was tested as before for phenol with negative results.

Hydrogen sulphid production.—This was determined in bouillon tubes in the upper portion of which were suspended strips of filter paper moistened with lead acetate solution. The moisture was renewed with distilled water as was deemed necessary. No signs of hydrogen sulphid appeared until the fourth day, when traces of the black sulphid of lead appeared upon the moist paper. The reaction became more pronounced as the age of the culture increased.

Toleration of acids.—Ordinary beef bouillon having a reaction of 0 Fuller's scale was used in this work. Hydrochloric and acetic acids were tested. Sufficient normal acid was added to 100 cc. portions of bouillon to secure a reaction of +5, +10 and so on for every 5 degrees Fuller's scale up to +50. Good growth resulted within 24 hours in tubes containing hydrochloric acid up to and including +20. Growth was observed in tubes having a reaction of +25 at the end of 2 days, and in 2 of the

¹ Prepared by heating one part of mercury with two parts of nitric acid, specific gravity 1.4, until the mercury was completely dissolved, and then diluting the solution obtained with twice its volume of distilled water. Salkowski & Orndorff. *Laboratory Manual of Physiological and Pathological Chemistry*, p. 251 (1904).

² Chester, F. D. *Manual of Determinative Bacteriology*, p. 33 (1901). Salkowski & Orndorff, pp. 106 and 161.

tubes having a reaction of +30 at the end of 4 days. No further change occurred thereafter during the 19 days the tubes were held under observation. Similar results were obtained upon the second series, growth being obtained upon 3 out of 5 tubes having a reaction of +30. In the third series 4 out of 5 tubes having a reaction of +30 showed growth. The organism was less resistant to acetic than to hydrochloric acid. Feeble growth occurred in 2 out of 5 of the tubes having a reaction of +20 Fuller's scale, and in the weaker solutions of acetic acid the growth was delayed and restricted.

Toleration of sodium hydroxid.—For this work 100 cc. portions of nutrient bouillon having a reaction of 0 Fuller's scale were measured out and to each was added the theoretical amount of N/1 sodium hydroxid to produce reactions of —5, —10, etc., every 5 degrees of Fuller's scale up to —45. The tubes were inoculated as soon as possible after sterilization under pressure, placed at room temperature, 20 to 24° C., and held under observation. Growth was observed at the end of 24 hours in tubes calculated to have a reaction of —5, and in one tube calculated to have a reaction of —10. At the end of 4 days growth was visible in all tubes calculated to have a reaction of —15, and in 2 out of 4 tubes calculated to have a reaction of —20. At the end of 7 days growth was observed in all tubes calculated for —20. At the end of 12 days growth was observed in all tubes calculated to have a reaction of —25. Thereafter no change occurred during the 19 days the tubes were held under observation. Transfers made from tubes which developed no growth after 19 days showed them to be sterile. Sterile control tubes of this broth calculated to have a reaction of —25, —30 and —35 were titrated at the end of 20 days and found to have a reaction of from —19 to —14. This change in reaction is of course to be attributed to the formation of sodium carbonate from the carbon dioxid of the atmosphere. The results however show that the organism is killed when introduced to beef broth medium containing sufficient sodium hydroxid to give a reaction of some-

thing less than —30 Fuller's scale, and that growth is at least slightly restricted in broth containing sufficient sodium hydroxid to give a reaction of —10. The second series of tubes was prepared in the same manner as those already described, inoculated, and placed in sealed glass jars containing a few cc. of 2% sodium hydroxid. At the end of 10 days the jars were opened and the tubes examined for growth. Those calculated to have a reaction of —5 all showed healthy development, but no growth was observed in tubes having a more alkaline reaction. Titration of a control tube of the —5 broth showed that the reaction had not fallen below —4 Fuller's scale. Tubes calculated to have a reaction of —10 tested —6.1 and —6.8 and those calculated to be —15 tested —10 and —11.

The third series was prepared in the same manner as the second, but was incubated in Novy jars filled with air from which the carbon dioxid had been removed by passing it through wash bottles containing sodium hydroxid and calcium hydroxid solutions respectively. The tubes were examined as well as could be, without opening the jars, at the end of 7 days and again at the end of 10 days. Growth was observed on both occasions in tubes having reaction of —5 but in no others. At the end of 24 days the jars were opened and the tubes examined critically for growth. All those calculated to have a reaction of —5 showed growth, but the stronger concentrations were inhibitory in all cases. Check tubes calculated to have a reaction of —5 were titrated and were found to react at from —3 to —5 Fuller's scale.

Optimum reaction.—As a basis for determining optimum reaction, nutrient bouillon having a reaction of 0 Fuller's scale was employed. Portions of 100 cc. each were treated with the requisite amount of hydrochloric acid or sodium hydroxid to give reactions at intervals of 5 points of Fuller's scale. Material was tubed, sterilized, and inoculated with a 2 mm. loop of broth cultures, and placed in the incubator at 25°. The most vigorous early growth occurred in tubes having reactions of +10 and

+15 Fuller's scale. The general appearance of the cultures as regards turbidity, pellicle formation and rate of development indicated that the optimum reaction is very close to +10 Fuller's scale.

Temperature relations.—The optimum temperature was determined in nutrient broth having reaction of +10 Fuller's scale. Cultures were incubated at 20, 25, 30 and 37° C. The best growth was obtained at 25° C. The maximum temperature was not much above 37° C. and only very feeble transient growth was obtained at body heat. No attempt was made to determine the minimum temperature, but growth was slow at 10° C.

Thermal death point determinations were made upon a very large number of cultures. For this work thin walled test tubes as uniform as possible and containing 10 cc. of nutrient broth were used. Inoculations were made from 18 to 24 hour old broth cultures. Great care was taken to avoid slopping the unheated inoculated broth upon the sides of the tubes above the level of the medium. Within an hour after inoculation the tubes were placed in a water bath so that the broth was well below the surface of the bath, and heated for exactly 10 minutes. The temperature was kept constant within .1° C. by a sensitive temperature regulator and a mechanical agitator. After removal from the bath the tubes were cooled in air and placed in the incubator at 25° C. The results of thermal death point determinations were not absolutely uniform but in nearly every case the death point was found to fall between 49 and 50° C. A few tubes heated at 50° showed growth, and in some cases growth occurred after heating at a fraction of a degree above 50. In a large majority of the cases the death point fell between 49.5 and 50° C. In no case did death result from heating for 10 minutes at less than 48.9° C.

Growth in carbon dioxid atmosphere.—Tubes of nutrient broth were heated to drive out the dissolved oxygen, cooled by dipping in cold water, quickly inoculated, and placed with con-

trols in a Novy jar, the cover of which was sealed with Darwin's wax mixture. Carbon dioxid prepared in a Kipp generator from boiled marble chips and chemically pure hydrochloric acid was passed successively through wash bottles containing 10% sodium carbonate, 10% potassium permanganate and boiled distilled water respectively, and then through the Novy jar. The cotton plugs employed were as loose as was consistent with the safety of the cultures and the jar was exhausted with the vacuum apparatus several times to aid in removing all oxygen. After carbon dioxid had passed through the jar two hours and a half it was sealed and incubated at room temperature. After 20 days the jar was opened and the tubes examined for growth with negative results. Within 24 hours after air was admitted to the culture all except the controls developed characteristic growth.

A second series of cultures was prepared in the same manner as the first except that a 2% dextrose nutrient broth was employed. Five days after inoculation fermentation became apparent in several tubes, as could be seen from the gas collecting in bubbles at the surface. After two weeks all inoculated tubes showed fair growth. Pellicle and ring formation were absent. The growth was characterized by a tendency to granular formation throughout the medium and the evolution of appreciable amounts of gas on agitation. When air was admitted to the cultures moderate clouding promptly developed and the usual aerobic characters appeared.

Desiccation.—For desiccation tests small portions of 24 hour old broth cultures were transferred to sterile cover slips in sterile Petri dishes. Only a very small amount of material was transferred and this was spread in a thin film on the cover slip. The preparations were allowed to dry at room temperature, 20 to 24°. Slips were transferred to tubes of nutrient broth with sterile forceps as soon as dry, and at the end of 3 hours, 17 hours, 24 hours, 41 hours, 50 hours, 6 days, 9 days, and 20 days. In no case was the organism killed by less than

6 days drying. In one of the 5 tests made no growth was obtained in a tube inoculated with a cover slip dried for 6 days. Growth occurred 2 days after inoculation with cover slips dried for 9 days. No growth occurred in tubes inoculated with cover slips dried for 20 days. Tubes were held under observation for 10 days after the cover slips were introduced.

Insolation.—Agar plates were sown with such dilutions as to produce from 100 to 200 colonies, and allowed to stand until thoroughly hardened. One-half of the plate was covered with an opaque screen, and the cultures exposed on ice to the influence of direct sunlight for 15 minutes. The exposure was made in the middle of the day on August 28. After exposure the plates were returned to the incubator and allowed to remain at a temperature of 25° for 3 days. The colonies were then counted upon exposed and unexposed portions of the plate, with results as follows:

	Exposed side 81 colonies	Unexposed side 117 colonies
	65 "	85 "
	58 "	80 "
	16 "	27 "
	20 "	50 "
	5 "	85 "
	13 "	40 "
Total,	258 "	484 "
Difference,	226 "	Calculated percent killed, 46.7

Production of alcohol.—Four different media were employed in the determination of alcohol production, viz.: 2% dextrose bouillon, 2% sucrose bouillon, potato broth, and maple sap. Inoculation was made in liter flasks in 500 cc. portions of media to which 10 gr. of calcium carbonate had been added immediately before sterilization. The cultures were held at room temperature, 20 to 24° C. After 10 days incubation the undissolved calcium carbonate was removed by filtration, the cultures made slightly acid with hydrochloric acid and then distinctly alkaline with sodium carbonate, the precipitated calcium car-

bonate removed, the filtrate distilled, and about 75 cc. of the distillate collected. A portion of the distillate was tested for alcohol and allied bodies by adding 5 to 6 drops of a 10% solution of potassium hydroxid, bringing the solution to a temperature of 50° C., and, then, adding a saturated solution of iodine in potassium iodide drop by drop until the liquid had a permanent brown color. After thorough agitation, the potassium hydroxid solution was added drop by drop until the color disappeared. In every instance a copious formation of iodoform resulted. None of the controls gave the precipitate. This reaction is not peculiar to alcohol, but is produced also by acetone, aldehyde, isopropyl alcohol, propylic and butylic alcohols and aldehydes, various ethers, meconic, laevulic, and lactic acids, turpentine, sugar, etc. On the other hand it is not given by methyl or amyl alcohol, chloroform, chloral, glycerin or ether; nor by acetic, formic or oxalic acids.¹ In general substances containing the group CH_3C linked to oxygen answer to the iodoform test.²

The iodoform producing bodies likely to be present in this distillate were alcohol or bodies belonging to the aldehyde or ketone groups. In order to determine if possible whether the body present was an alcohol, aldehyde or ketone, or whether all three were present, portions of the distillate were subjected to the following tests:

1. A few drops of 10 percent sodium hydroxid were added to a few cc. No distinctive reaction occurred, but upon standing a small amount of slimy or slightly resinous precipitate collected at the bottom of the tube. This was present, however, in only minute amounts.

2. A solution of Merck's phenol dissolved in excess of sulphuric acid when treated with a few cc. of the solution gave no characteristic scarlet color.

¹ Allen. Commercial Organic Analysis, 1, p. 91 (1903).

² Holleman, A. F. Textbook of Organic Chemistry, p. 173 (1903).

3. Hot Fehling's solution in excess was reduced by a portion of the distillate, giving characteristic copper precipitate.

4. A saturated cooled solution of acid sodium sulphite treated with a portion of the distillate gave no reaction.

5. The color of a solution of fuchsin, mixed with just sufficient sodium sulphite almost to decolorize it, was not restored by the addition of 5 cc. of the distillate, although in some cases there appeared to be a slight suggestion of returning color.

6. A 10% solution of silver nitrate was treated with an equal quantity of 10% solution of potassium hydroxid and ammonia was added until the precipitate just dissolved. A portion of the distillate added to this reagent gave a metallic mirror after standing for half an hour, or within one or two minutes when the tube containing the mixture was gently heated over a flame.

The indications were that while aldehyde or ketone or both might be present in small quantities, the greater part of the iodoform must have been produced from alcohol. As a further check upon this conclusion 50 cc. of the distillate producing iodoform were added to an excess of hot Fehling's solution and the containing flask immediately connected with a condenser and distilled. About 20 cc. of the distillate were collected. An examination of the residue in the Fehling's solution showed a reduction of copper. The distillate gave a copious precipitation of iodoform, but failed to react with ammoniacal silver nitrate or with decolorized fuchsin.

Production of proteolytic enzymes.—The slow liquefaction of gelatin in old cultures and the suggestion of partial digestion observed in old milk cultures indicates that this organism produces proteolytic enzymes only when forced to do so and then only in very small quantities. In order to determine this point fresh centrifuged milk was passed through several thicknesses of fine meshed filter paper, and finally freed from the last traces of fat, and at the same time rendered sterile, by passing it

through a Pasteur filter. Portions of 50 cc. each were removed to sterile flasks by means of sterile pipettes and inoculated with the organism. The cultures were held at 25° C. and tested for proteolytic action at intervals from 10 to 44 days, always with negative results. The test was made by adding to the culture in the flask 75 grams of ammonium sulphate, heating in a water bath at 60° C. for 30 minutes to precipitate all proteids except peptones and propeptones, filtering, rendering the filtrate strongly alkaline with potassium hydroxid and testing with a few drops of a 1% solution of copper sulphate.¹

Production of diastatic ferments.—A thin starch paste to which was added 2% of sugar free thymol was prepared and added to equal parts of 10 day old broth cultures. After incubation at 25° for 6 to 8 hours the solution was filtered and tested for reducing sugar with Fehling's solution. The results were negative.

Production of invertase.—A solution containing 2% of cane sugar and 2% of phenol was prepared for the purposes of this test. Equal quantities of 10 day old broth cultures of the organism and this solution were thoroughly mixed and left in the incubator over night. The unclarified solution when tested with Fehling's solution gave a pronounced change of color with a variable amount of copper precipitate, but the reaction was so far from characteristic that a check upon the work was desired. It is customary in analysis of solutions for invert sugars to clarify with some substance, such as neutral lead acetate or copper sulphate, before proceeding with the analysis. In the use of lead acetate it is important to avoid a large excess and it is necessary to remove the slight excess used by precipitation with calcium oxalate before proceeding with the Fehling test. In order to determine the influence of clarification of bacterial cultures before running the Fehling test the following solutions were prepared:

¹ Salkowski and Orndorff, loc. cit., pp. 15 and 46.

1. A solution containing 2% of phenol, 2% of sucrose, and .2% of dextrose.
2. A solution containing 2% of phenol, 2% of sucrose, and .2% of dextrose, together with an equal volume of sterile bouillon.
3. A solution containing 2% of phenol, 2% of sucrose, .2% of dextrose and an equal volume of a 10 day old broth culture of the organism.
4. A solution containing 2% of phenol, and 2% of sucrose.
5. A solution containing 2% of phenol, and 2% of sucrose, together with an equal volume of sterile bouillon.
6. A solution containing 2% of phenol, 2% of sucrose, together with an equal volume of a 10 day old broth culture of the organism.
7. A solution containing 2% of phenol.
8. A solution containing 2% of phenol, together with an equal volume of sterile bouillon.
9. A solution containing 2% phenol, together with an equal volume of a 10 day old broth culture of the organism.
10. A solution containing sterile bouillon.
11. A solution containing a 10 day old broth culture of the organism.

Three 10 cc. portions A, B, and C of each solution were taken. To the solutions A, 1 cc. of a strong solution of lead acetate was added. They were filtered, the excess of lead acetate precipitated with potassium oxalate crystals, care being taken to avoid an excess of potassium oxalate. The lead oxalate was filtered off and the filtrate reserved for treatment with Fehling's solution. Portions B were treated with 1 cc. of copper sulphate solution used in connection with the Fehling's solution. Portions C were given no preliminary treatment before using the Fehling test. The precipitation was carried out in Erlenmeyer flasks. By means of a pipette 10 cc. of the copper solution was placed in the flask, then 10 cc. of the tartrate, care being taken to avoid gathering undissolved precipitate on the walls. The two were mixed and heated to boiling. A 10 cc. portion of the solution to be

tested was added to the mixture which was again brought to a boil and maintained at gentle ebullition for 2 minutes. It was then removed from the hot plate and transferred to a porcelain evaporating dish and left to settle for a few minutes. The liquid was decanted and the bottom of the dish examined for precipitated copper. The following table shows the results obtained. The presence of precipitated copper is indicated by the sign +, and its absence by the sign —. Where only a very minute precipitate was obtained it is indicated by the word "trace."

Prelim'y treatment	A Lead acetate	B Copper sulphate	C	Character of solution
1	+	+	+	phenol, sucrose, dextrose.
2	+	+	+	phenol, sucrose, dextrose, bouillon.
3	+	+	+	phenol, sucrose, dextrose, culture.
4	—	trace	trace	phenol, sucrose.
5	—	—	—	phenol, sucrose, bouillon.
6	trace	trace	+	phenol, sucrose, culture.
7	trace	trace	—	phenol.
8	—	—	—	phenol, bouillon.
9	—	—	—	phenol, culture.
10	—	—	—	bouillon.
11	—	—	—	culture.

The reaction in series A and B was in general characteristic. In series C, numbers 1 and 4 were characteristic, number 2 was nearly so, while numbers 3 and 6 gave a muddy solution with an uncharacteristic color and, in addition to the copper oxid, the precipitate contained a brown, light weight, flocculent material.

Cultures upon potato slants 4 days old were washed with distilled water, the washings were filtered and tested for reducing sugars with Fehling's solution with negative results.

Effect of germicides.—The germicidal effect of formaldehyde and of phenol were tested in broth cultures of the organism by adding definite known quantities of these germicides to tubes of sterile medium and then inoculating with a 2 mm. loop of young broth culture.

Formaldehyde.—As a basis for this work a guaranteed 40% formaldehyde was employed. One cc. of the solution was added

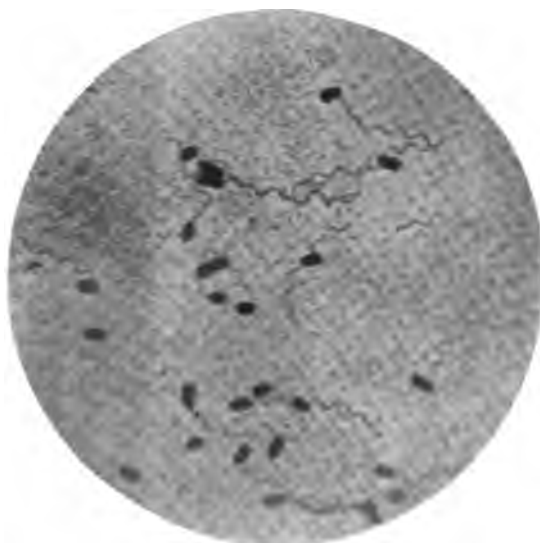


PLATE XI.—*Ps. fluorescens* var. *non-liquifaciens*, strain CXL. Flagella preparations from 24-hour agar slant, (Loeffler's stain). (See page 555.) $\times 1500$.

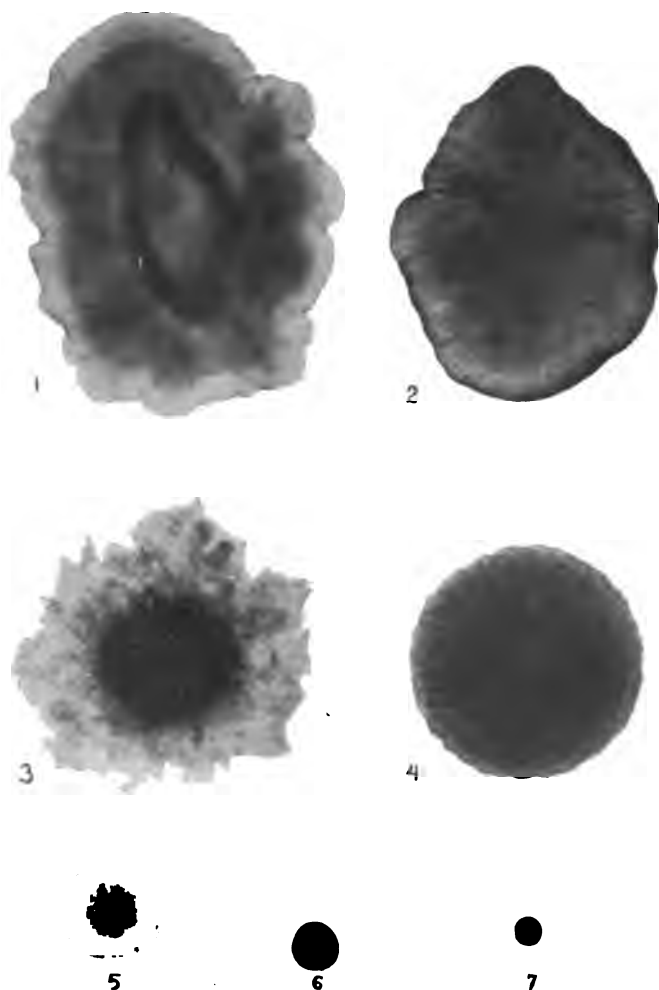


PLATE XII.—*Ps. fluorescens*. Types of gelatin colonies. Figures 1 and 2. Strain LIII (two day colony). Figures 3 and 4. Strains LVI and 5 (two day colonies). Figures 5, 6 and 7. Strains XXXIII (two day colony) XXXVI and XXXIII (one day colonies). (See pages 567-568.) $\times 75$.

to flasks containing 49, 99, 149 and 199 cc. respectively of distilled water. From each of these flasks portions of 1 cc. were withdrawn with sterile pipettes and placed in test tubes containing 10 cc. of broth, thus making dilutions of 1-550, 1-1100, 1-1650 and 1-2200 respectively. Eight tubes of each dilution were prepared, 5 tubes were inoculated with a 2 mm. loop of a 24 hour old broth culture, and 3 were retained as controls. Incubation was at 25° C. No growth had developed in any of the tubes at the end of 2 days. On the fourth day growth was observed in one of the five tubes containing 1 part of formalin to 2200 of water. Thirteen days after inoculation transfers were made into sterile broth. The transfers from the tube showing growth developed a characteristic appearance but those from the other tubes remained unchanged. In the second series 1 cc. of 40% formaldehyde was added to flasks containing 199, 249 and 299 cc. respectively of distilled water. One cc. portions were transferred with sterile pipettes to tubes containing 10 cc. of broth, thus making dilutions of approximately 1 part of formalin in 2200, 2750, and 3300 parts respectively. As in the previous instance 5 tubes were inoculated and 3 retained as checks. Within 24 hours growth appeared in 3 of the 5 tubes containing 1 part of formalin to 3300. The second day growth was evident in all of the tubes containing 1 part of formalin to 3300 and in one of the tubes containing 1 part to 2750. The cultures 6 days old showed growth in all tubes of the weakest dilution, in 3 of the 5 tubes containing 1 part formalin to 2750 of the medium, and a very slight growth in one of the tubes containing 1 to 2200. On the eleventh day the tubes had all cleared except one containing formalin in the proportion of 1 to 3300. This tube showed strong clouding.

Phenol.—The phenol employed in this work was Merck's phenol, U. S. P. VII. This was melted by placing the container in warm water. To a portion was added 11% of water by weight, thus obtaining a solution which remained liquid at ordinary temperatures. One cc. of this liquid phenol was added to 9, 49, 99, 149, and 199 cc. respectively of distilled water. One

cc. portions of these various dilutions were added with sterile pipettes to tubes containing 9 cc. of sterile broth, thus making dilutions of 1-100, 1-500, 1-1000, 1-1500, and 1-2000 of liquid phenol in broth. As in the case of the formalin 5 tubes were inoculated and 3 retained as checks. Growth was observed at the end of a day in all tubes containing 1 part liquid phenol to 2000 parts of broth, and in those containing 1 part to 1500, while four of the five tubes containing 1 part of liquid phenol to 1000 parts of broth, showed slight clouding. Good growth eventually developed in all tubes containing 1 part to 1000. No further change was observed in these tubes during the 2 weeks they were held under observation.

Nitrogen requirements.—The water used in the study of the nitrogen requirements of the organism was re-distilled with potassium permanganate, after which a third distillation employing sulphuric acid was carried out. Only chemicals of known purity were employed, except in the case of glycerin which, while of a high grade of purity, was not free from traces of nitrogen.

The following formulas were used:

A.	B.	C.
Sodium chlorid, 6 grams.	Sodium chlorid, 6 grams.	Sodium chlorid, 6 grams.
Calcium chlorid, .10 gram.	Calcium chlorid, .10 gram.	Calcium chlorid, .10 gram.
Magnesium sulphate, .35 gram.	Magnesium sulphate, .35 gram.	Magnesium sulphate, .35 gram.
Di-potassium phos- phate, 2.2 grams.	Di-potassium phos- phate, 2.2 grams.	Di-potassium phos- phate, 2.2 grams.
Glycerin (Merck's blue label), 35 grams.	Mannit, 35 grams.	Dextrose, 35 grams.
Water, 1000 cc.	Water, 1000 cc.	Water, 1000 cc.

Each of these solutions, A., B., and C., were divided into five portions, one of which in each case was reserved as a control. To the other four were added 1% of asparagin, urea, ammonium chlorid, and potassium nitrate respectively. The media were tubed and sterilized in the autoclave for 15 minutes under 5 pounds of steam.

Series A. *Glycerin*.—As would be expected, growth developed in the control tubes of series A where glycerin was employed as a source of energy, since they were not nitrogen free. Growth became apparent the third day, but was slight and transient. The tubes containing potassium nitrate appeared exactly like the controls. The asparagin tubes developed growth in six days which increased, becoming very pronounced in two weeks. At no time did development occur in tubes containing urea or ammonium chlorid.

Series B. *Mannit*.—No growth occurred in the controls or in tubes containing potassium nitrate. Very feeble growth was observed with ammonium chlorid and with urea. The asparagin tubes showed growth the sixth day which became very pronounced. A deep milky color appeared, and a thick, tough, pellicle formation and heavy sediment developed.

Series C. *Dextrose*.—The controls gave no growth. Potassium nitrate, ammonium chlorid and urea all developed feeble growth, which was less transient in the case of ammonium chlorid than with potassium nitrate. Asparagin again gave a luxuriant growth after a period of delay. The development upon asparagin was better when dextrose was used than when either glycerin or mannit was employed. Moreover the organism seemed to be able to make slight development upon potassium nitrate in association with dextrose but not when mannit was substituted, and apparently not when glycerin was substituted. Urea and ammonium chlorid supported feeble growth with mannit and dextrose but not with urea. The results are summarized in the following table in which the sign — denotes no growth, + feeble growth, ‡ abundant growth after delay, and ? transient growth probably attributable to nitrogen derived from the glycerin.

TABLE 47. GROWTH ON NITROGENOUS MEDIA

	A. Glycerin	B. Mannit	C. Dextrose
Control,	?	—	—
Asparagin,	‡	‡	‡
Urea,	—	+	+
Ammonium chlorid,	—	+	+
Potassium nitrate,	?	—	+

NAME

A careful comparison of the cultural and biochemical characters of this organism with those of bacteria previously described would seem to justify its recognition as a new species. The name *Bacillus aceris* (new species) is therefore suggested for it.

B. BRIEF DESCRIPTION OF THE PINK COCCI OF MAPLE SAP¹

Pink colonies were frequently found upon the plates poured from sour sap, particularly late in the season. Some of these were produced by yeasts or yeast-like organisms while others were composed of micrococci. Four strains were selected for further study from the cultures of pink micrococci isolated. These were CXXVI, CIV, XLIX, and CVI. A brief description of the organisms is given here for the purpose of record. All appear to belong to the type of *Micrococcus roseus*. They resemble each other closely and will be described as though identical, any variations in behavior from the general type being noted as they occur.

MORPHOLOGY

Vegetative cells.—The organisms are coccoid in form, occurring singly, in twos, fours, or irregular packets. Division is in two planes. The average diameter as determined on agar hanging block cultures was 1.2 microns. The smallest organisms observed measured .8 micron and the largest 2. microns. Cultures in nutrient broth had a tendency to be somewhat smaller and to occur singly or in twos.

Spores.—Evidences of spore formation were absent.

Flagella.—The organisms were non-motile and no indications of flagella were observed.

¹The matter appearing on pages 516-521 is briefed from a thesis entitled "The Pink Micro-Organisms of Maple Sap," presented by N. R. Smith, B. S., of the class of 1911, in partial fulfillment of the requirements for the baccalaureate degree in the College of Agriculture of the University of Vermont.

Capsule.—There was a tendency to develop a slimy sediment in liquid cultures, but microscopic examination and staining methods failed to demonstrate a capsule.

Zooglea.—No evidence of zooglea masses was observed.

Involution forms.—Involution forms were not observed.

Staining reactions.—The organisms stained readily in 1-10 cold watery fuchsin, gentian violet, Loeffler's alkaline methylene blue, and carbol fuchsin. The method of Gram gave negative or sometimes doubtful results.

CULTURAL CHARACTERS

Agar stroke.—Growth was moderate becoming visible two days after inoculation. It was raised, regular, slimy, and tinged with pink. Iridescence developed after 10 days, the growth having spread to a width of 4 to 5 mm.

Agar stab.—Slight growth became visible after 24 hours. The second day a characteristic surface colony appeared. The growth in old cultures (6 to 8 weeks) became villous along the line of puncture. Colonies were first gray, and then became pink. When 7 days old they were from 2 to 4 mm. in diameter, raised, shiny, and pigmented. The edge was regular, thin and transparent, and the center opaque.

Two percent sucrose litmus agar.—Growth was confined to the surface, and characterized by the production of pink pigment. Acid was produced but the litmus was not reduced.

Two percent dextrose litmus agar.—Acid production became apparent the second day. Reduction of the litmus began after one week and progressed slowly until complete about the fourth week.

Two percent lactose litmus agar.—Growth was slight, acid formation and litmus reduction both being absent.

Five percent glycerin litmus agar.—The growth was slow and acid production absent. Feeble litmus reduction was noted on the fifth day, and thereafter progressed slowly, becoming complete after two weeks.

Potato.—Organisms failed to develop visible growth upon cooked potato slants.

Gelatin stab.—Growth was slow, moderate, at first beaded along the line of puncture, becoming filiform above. Slight liquefaction began on the twenty-fourth day and continued slowly, becoming stratiform in six weeks. The liquefied gelatin became pinkish, contained a compact pink sediment and was distinctly viscid.

Gelatin plate.—Colonies appeared the third day, and attained a diameter of 2 mm. in 10 days. They were convex with round entire edges. The pigment upon gelatin was similar to that upon agar except that it was usually of a darker hue.

Broth.—First evidences of growth consisted of a slight, compact, pinkish sediment appearing the second or third day, while clouding appeared in one week. The sediment was viscid on agitation.

Milk.—The first evidence of growth consisted of a deposition of pink sediment, becoming apparent within the first 10 days. In 3 weeks the medium was colored light pink while a watery appearance developed the fourth week. This appeared to be associated with feeble digestive action, although complete peptonization did not occur. Coagulation did not take place.

Litmus milk.—The organisms studied developed considerable variation upon this medium. CXXVI showed acid formation after 14 days, with coagulation 2 or 3 days later, promptly followed by the reduction of the litmus in the lower part of the tube. Partial digestion of the curd occurred. The first evidences of peptonization appeared during the third week and progressed slowly until about the ninth week, when about half of the total curd had become dissolved. CIV exhibited no change in the medium until after 6 weeks, when it turned alkaline and curdled. Digestion did not occur. XLIX became alkaline the third week and developed a soft curd 3 or 4 days later. Litmus reduction occurred after 4 weeks. Partial liquefaction of the coagulum was observed in about half of the cultures of this strain, but did not

occur in the remainder. CVI curdled milk after 5 weeks with reduction of litmus. The color was restored with an alkaline reaction in the upper half of the tube after 8 weeks. No digestion of casein was observed.

The variations upon litmus milk were so great that the work was repeated several times and the purity of the cultures carefully verified, but without change in the character of the reaction.

Cohn's solution.—A slow growth was noted which was characterized by the development of sediment which usually was granular and flaky, but sometimes slightly viscid.

Uschinsky solution.—The growth was slow, at first moderate in amount, becoming abundant after 5 weeks, with copious sediment. A portion of the culture immediately above the sediment exhibited clouding.

Growth in bouillon over chloroform.—There was no growth in bouillon tubes to which 2 or 3 drops of chloroform were added.

PHYSICAL AND BIOCHEMICAL FEATURES

Acid production.—Nutrient broths to which were added 2% of various sugars and 5% of glycerin respectively were tested for gas formation and acid production in fermentation tubes. In no case was there sufficient gas production to become apparent with the Smith tubes. Ten cc. portions were titrated in the usual way at the end of 1, 2, 4, 10, and 28 days. The reaction of duplicate checks was subtracted from the average reaction of inoculated duplicates to determine the average acid or alkali production. The results expressed in percent normal are shown in the following table.

TABLE 48. ACID PRODUCTION ON CARBOHYDRATE BROTHS

	1 day	Dextrose 2 days	4 days	10 days	28 days
CXXVI,	— .13	— .08	— .05	.11	.45
CIV,	— .07	— .03	— .03	.22	.38
XLIX,	— .10	— .03	.07	.10	.40
CVI,	.10	.09	.06	.08	.39
Sucrose					
CXXVI,	.06	.12	.03	.14	.56
CIV,	.08	.08	.03	.32	.62
XLIX,	.02	.05	.06	.07	.30
CVI,	.05	.10	.04	.11	.68
Lactose					
CXXVI,	— .09	— .05	— .11	— .08	.60
CIV,	— .04	— .08	.06	— .10	.04
XLIX,	— .06	— .10	.01	— .08	.02
CVI,	— .03	— .04	— .08	— .08	.42
Glycerin					
		10 days		20 days	
CXXVI,		— .05		.10	
CIV,		.05		.00	
XLIX,		.00		— .05	
CVI,		— .24		.25	

Nitrate reduction.—Cultures grown in nitrate broth were tested for nitrites at the end of 5, 10 and 15 days, with uniformly positive reaction. Other cultures were tested with Nessler's reagent for ammonia with negative results.

Hydrogen sulphid.—Cultures on nutrient broth were tested for hydrogen sulphid production by means of moist filter paper, bearing lead acetate, suspended from the plug. No evidences of this gas were observed.

Indol production.—Cultures on Dunham's solution and on peptone water were tested for indol production with negative results.

Temperature relations.—The optimum temperature was from 20 to 25° C. The maximum was slightly above 40° C. Growth occurred at 10° but not at 4° C.

Thermal death point.—Thermal death point determinations were made by exposing young transfers in thin wall test tubes at various temperatures, in a constant water bath for ten minutes

XLIX failed to grow in tubes exposed at 44° C. or above, CIV at 46° C., and CXXIV and CVI at 48° C.

Desiccation.—Sterile cover glasses were placed in Petri dishes and inoculated, each with a loop of media from a 12 day old broth culture, and allowed to dry for intervals varying from the first instant when the cover glasses were free from the film of moisture up to 30 days. Their viability was tested by transferring the cover slips to tubes of broth by means of sterile forceps. The cultures were held for two months but in every instance failed to show growth.

Insolation.—Thinly sown agar plates were exposed on snow to direct sunlight for 30 minutes with one-half covered. After a period of incubation the colonies which developed on the exposed and unexposed portions of the plates were counted. There was practically no difference in the number of colonies developing.

Pigment formation.—Pigment formation occurred only in the presence of oxygen and at ordinary temperatures. It failed entirely at 37° C. Upon solid media such as agar and gelatin each coccus had its peculiar tinge of pink. An attempt was made to refer these colors to the chart given by Winslow,¹ as follows:

CXXVI	=	Orange red	III & IV.
CIV	=	Orange red	IV.
XLIX	=	Orange yellow	VI.
CVI	=	Orange red	III & IV.

The pigment was insoluble in water, dilute sulphuric acid, xylol, cold or hot alcohol, and chloroform. In dilute nitric acid the growth was disintegrated and the pigment dissolved slightly.

C. THE GREEN FLUORESCENT BACTERIA OCCURRING IN MAPLE SAP

INTRODUCTION

Bacteriological literature contains descriptions of more than 50 species of bacteria which are capable of producing a green fluorescent pigment. Such bacteria were originally assigned to

¹ Winslow. *Systematic Relationships of the Coccaceæ* (1908).

various widely separated groups, the early writers recognizing the ability to form the fluorescing pigment as a valuable diagnostic character, but apparently failing to consider a possible phylogenetic relationship. In the light of the intimate relationship revealed by the more critical studies of the later investigators, all green fluorescent bacteria are now classified in the *Pseudomonas* group of Migula. Moreover it is now recognized that many of the described species are identical, while the characters of others grade into each other so imperceptibly that present bacteriological methods fail to demonstrate specific constant differences upon which differentiation may well be based.

The members of the group are widely distributed. They are almost universally found in the presence of putrefying organic material, and are abundant in soil, water, and air. They are recognized as one of the most common types of water bacteria. Schmelck (26:546) noted that the predominating organisms in glacial waters were of this sort, and Harrison (12) and Belli (2) observed *B. fluorescens liquefaciens* in hail. Jensen (13:613) states that the fluorescent organisms occur in butter, while Thöni (30:623) noted their presence in fifteen samples of lemonade which he analyzed. Griffon (11) claims that *B. fluorescens liquefaciens* and *B. fluorescens putrida* are capable of producing wet rots of certain vegetables. The former has been reported as the causal organism in a carrot rot, while tobacco anthracnose is attributed to *B. aeruginosus*, which according to Griffon, is synonymous with *B. fluorescens putrida*. Tomatoes grown under glass have also been attacked by a stem canker said to be due to *B. fluorescens*. Although the majority of fluorescent bacteria are harmless, certain species are reported as pathogenic to animals. It is therefore evident that the bacteria of this group are capable of existing under a variety of conditions.

Fluorescent bacteria play a leading role in the deterioration of maple sap. Fresh drawn sap of the early "runs" is water clear and has a clean sweet flavor, but with the advent of warmer weather it becomes more or less cloudy and a disagreeable flavor

develops. Such sap is popularly called sour, and several types are recognized among which the most common is the so-called green sap. In all the samples of greenish or greenish-brown sap examined, the predominating organisms were of the fluorescent type, and inoculation experiments have repeatedly demonstrated their causal relationship to this type of spoiled sap.

The initial infection of the sap is doubtless brought in from the bark of the tree, by wind, and by dripping rain and snow water. Falling snow and rain also probably bring in some infection from the air. Fluorescent bacteria were demonstrated on the tree bark as well as in the snow and surface water and in unwashed buckets and spouts from the previous season. Large numbers of the organisms remain in the spout and buckets from season to season, unless these are thoroughly cleansed by boiling.

Such maple sap organisms of the fluorescent type as have been previously reported upon (4:492) were recognized as members of the *Pseudomonas* group of Migula and more or less closely related to *Pseudomonas fluorescens*. Both the liquefying and non-liquefying types were observed.

On account of the prevalence of this type of bacteria in maple sap and their importance in the maple sirup industry, a critical study of the characters of the group was considered important. The discussion falls naturally under two heads:

(1) A preliminary investigation with 42 strains of green fluorescent sap bacteria.

(2) A more exhaustive comparative study of seven representative strains selected in the preliminary work and of six known species.

PRELIMINARY STUDIES UPON 42 STRAINS OF GREEN FLUORESCENT SAP BACTERIA

ISOLATION

The 42 strains of green fluorescent sap bacteria were selected from several hundred cultures isolated from abnormal maple sap secured in different parts of Vermont during four successive

sugar seasons. The numbers of the strains selected, the dates of isolation and the sources are as follows:

Strain	Date of isolation		Source
CXII,	4/4/09	Randolph.	Sour tree, Orchard 1
CXV ¹ ,	"	"	Second sour tree, Orchard I.
CXXVII,	4/5/09	"	Third sour tree, Orchard I.
CXXVIII,	4/12/09	"	Green sour sap employed in making sirup 24 (p. 358).
CXXIX,	"	"	
CXXX,	"	"	
CXXXIII,	4/12/09	"	Green sap, Orchard II.
CXXXIV,	"	"	
CXXXV,	"	"	
CXXXVII,	"	"	
CXXXVIII,	"	"	
CXXXIX,	"	"	
CXL,	4/12/09	"	Milky sap, various orchards.
CXLI,	"	"	
CXLII,	"	"	
CXLIII,	"	"	
CXLV,	"	"	
CXLVI,	"	"	
CXLVII,	"	"	
CXLVIII,	4/13/09	"	Greenish-yellow sour sap from same tree as sirup 26 (page 358).
CXLIX,	"	"	
CL,	"	"	
CLI,	"	"	
CLII,	"	"	
CLIII,	"	"	
CLIV,	"	"	
CLV,	"	"	
CLVI,	"	"	
CLVIII,	"	"	
CLIX,	"	"	
CLXXVII,	"	"	
CLXXXIX,	"	"	
5	4/27/07	E. Montpellier	Sour sap.
XVI,	2/1/08	Burlington	Sour sap.
XXXIII,	4/11/08	Bethel	Sour sap.
XXXVI,	"	"	
XXXVIII,	"	"	
L,	4/18/08	Fairfax	Sour sap, Orchard I.
LI,	"	"	
LIII,	"	"	
LIV,	4/18/08	"	Sour sap, Orchard II.
LVI,	"	"	

¹ Doubtfully fluorescent.

METHODS OF WORK

Throughout the studies great care was exercised to secure uniformity of methods so that the results with the several strains might be comparable. In general the methods recommended in "Standard Methods of Water Analysis" (1905) and in Smith's "Bacteria in Relation to Plant Diseases" (27) have been followed, but in certain respects it has been deemed wise to introduce variations. The most important of these is the substitution of "Liebig's Extract of Meat" for beef infusion. Media prepared with meat extract has been used in this laboratory for several years and has always given satisfaction. It is believed that media prepared in this way is more uniform in composition than that from infusion and it also possesses the very decided advantage of being free from muscle sugar. Actively fermenting strains of *B. coli* develop in it without producing visible gas. The objections usually advanced against meat extract that it frequently contains resistant spores, that it may have been treated with preservatives, or that it may contain injurious by-products of bacterial development, have not seemed to be well founded. In our experience there is never more difficulty in sterilizing meat extract than in sterilizing beef infusion and we have never been able to discover indications of preservatives or injurious decomposition products, the most sensitive organisms developing as readily upon one type of medium as upon the other. When cultures are to be employed in studying gas evolution or acid formation, muscle sugar introduces a complication. It is the general custom to remove this by cultivating an active fermenter in it for a few hours. This is objectionable and is certain to introduce decomposition products to such an extent as to render the media quite unfit for the development of certain sensitive species. There is great need of synthetic substitutes for the beef media composed of synthesized chemicals, but until they are developed we believe the employment of a standard brand of meat extract has points of advantage over infusion.

The details necessary for duplication of our media are given below for the convenience of any one who may have occasion to review the results. Unless otherwise noted, media were prepared with a distilled water of high purity and adjusted against phenolphthalein to a reaction of +10 Fuller's scale. Sterilization was effected by exposing in the autoclave at 6 pounds pressure for 15 minutes, except with milk, potato, gelatin, and carbohydrate and glycerin media which were steamed in the Arnold for 15 minutes on each of three successive days.

Nutrient broth.—Ten grams of "Witte's Peptonum Siccum" and 5 grams of "Liebig's Extract of Meat" were added to one liter of distilled water and cooked in a double cooker until dissolved (about 30 minutes), restored to volume, titrated and adjusted in reaction to +10 Fuller's scale, cooked in double cooker 20 to 30 minutes, boiled 5 minutes over the open flame, titrated and adjusted in reaction if necessary, filtered and sterilized.

Agar medium.—This medium was prepared by adding 1.5% of Bausch and Lomb agar flour to the nutrient broth, with subsequent autoclaving, adjusting of reaction to +10 Fuller's scale, and clearing with either fresh white of egg or dried albumen.

Gelatin medium.—Nutrient broth was stiffened with 12% of "Nelson's Photographic Gelatin No. 1" unless otherwise specified. The broth was heated, the gelatin added, steamed a few minutes in the Arnold, adjusted to +10 Fuller's scale, cooled, cleared with egg albumen, filtered, and sterilized by the intermittent method.

REJUVENATION AND STOCK

The organisms were rejuvenated as recommended by transferring to nutrient broth, incubating 24 hours, transferring from the young culture to a second tube of broth, incubating 24 hours again, and so on for three days. Plates were poured from the third tube of broth to insure the purity of the strain and transfers from the colonies were made to tubes of agar and broth. The agar and broth series was transferred monthly

and from it, as a parent stock, a sub-stock was maintained. From the sub-stock an inoculation stock was rejuvenated occasionally and subjected to retransfer every 24 to 48 hours. Frequent replating assured the purity of the strains. Unless otherwise stated inoculations were made from 24 to 48 hour broth cultures and incubation was at 25° C. Gelatin media were incubated at 20° C.

DETAILED FEATURES OF THE FORTY-TWO STRAINS

The immediate object of the preliminary studies was to separate the forty-two strains of fluorescent bacteria into groups, in order that type organisms might be selected for a more exhaustive study. To this end attention was directed primarily toward the characteristics which are expressed by the group number, (Descriptive Card, Society of American Bacteriologists); but considerable additional data was secured on the morphological, cultural, physical and biochemical characters of the organisms. Therefore the discussion of the preliminary work follows in a general way the detailed features as outlined in the Society Card. For the group numbers of the strains and the method of separating the series into groups, see pages 550-551.

I. MORPHOLOGY

1. *Form*.—The organisms are all motile rods. Preparations from 24 hour agar slant cultures of all strains stained by Löwit's method for flagella showed that some strains typically have one, and others three or six, polar flagella, chains frequently exhibiting numerous long flagella in a polar tuft. Strain CXV also has lateral flagella (c. f., pp. 546, 555).

2. *Grouping*.—Short chains of two cells were typical but longer chains were not uncommon. A surface scum or pellicle was usually present on liquid media.

3. *Motility*.—Rapidly and quite persistently motile.

4. *Endospores*.—None were demonstrated with stains or by thermal death point determinations. Several common spore

stains were applied on material from many media and, except for polar bodies, were without result.

5. *Capsules*.—Broth cultures of the three strains, XXXIII, CXV, and CXLV, were commonly stringy. Capsules were demonstrated on these strains, both by Welch's method and by Richard Muir's contrast stain. Attempts to demonstrate capsulation on some of the other strains were unsuccessful.

6. *Stains*.—All strains, except CXV, were Gram negative, though decolorization was not always complete, granulations in the rods and polar bodies being common. Strain CXV retained Gram's stain after 4 minutes in absolute alcohol.

Aqueous anilin stains.—Cells of all strains were easily stained, but gave up the dye readily on washing. The rods often showed granulation or a bi-polar effect, certain portions seeming to have a greater affinity for the stain than others.

II. CULTURAL FEATURES

1. *Agar stroke*.—Growth abundant, filiform to echinulate, spreading below; raised, smooth, glistening and somewhat viscid or slimy. Medium more or less green fluorescent with all strains. Strain CXV showed at most only a doubtful fluorescence.

2. *Potato*.—Growth moderate with all strains. A rather narrow, smooth, filiform, light brown streak, becoming thick and spreading later. Medium sometimes greened but not invariably. Strain CXV often showed a dull rhizoid growth.

3. *Agar stab*.—Best development at top of puncture but considerable sub-surface growth later. Filiform, becoming villous. Varying degrees of green fluorescence. Long crystals were common in old cultures; they occurred under the surface growth and about the puncture and were never detected in control tubes. Similar crystals are illustrated by Smith (27:66). Beautiful green fluorescence, varying somewhat in intensity with the various strains. Strain CXV was doubtfully fluorescent.

4. *Gelatin*.—Nutrient broth, stiffened with 10, 12, and 15% gelatin, was used. Several complete sets of the strains were

tested out at 20° C. with similar results. The growth was best at the top with the puncture beaded to filiform. Restricted development occurred along the puncture below the liquid gelatin. Crateriform liquefaction becoming stratiform was typical of the group. The reaction began in from 16 hours to 3 to 5 months. Several weeks or longer was required to complete the liquefaction of 7 cc. of the medium. Fluorescence was not marked, old cultures showing it only faintly.

One set of cultures in duplicate held under observation over eight months yielded noteworthy results. Seven strains began a typical liquefaction after from three to five months, but the time required for complete liquefaction of 7 cc. was not determined. At the end of 8½ months control plates were poured and the organisms found to be present in pure culture. The organisms recovered were fluorescent and capable of producing hydrogen sulphid, the latter property being peculiar to these seven strains.

5. *Nutrient broth*.—A surface scum or a thin membranous pellicle, often wrinkled, was usually present. Clouding was strong at first, the medium becoming yellow-green fluorescent and clearing with a deposition of a more or less coherent sediment.

6. *Milk*.—Fresh centrifuged milk reacting +12 to +14 Fuller's scale, and sterilized by the fractional method, was used. In from one to ten days a watery layer appeared at the surface with a jelly-like thickening and greenish discoloration of the substratum in all cultures except those of the following strains: CXL, CXLI, CXLII, CXLIII, CXLVI, CXLVII, XVI, XXXVI, L, LI, and LIV. After 35 days' incubation, CXLVII, XVI, XXXVI, XXXVIII, LI, and LIV showed doubtful clearing. Strains CXL, CXLI, CXLII, CXLIII, CXLVI, and L in all trials remained unchanged for about 3 months, when a very slow digestion appeared.

7. *Litmus milk*.—Litmus milk was prepared by the addition of 2% of a saturated solution of chemically pure litmus to fresh centrifuged milk and which was then sterilized by the intermittent method.

Without enumerating the details of the minor differences observed with the several strains the characteristics on this medium may be summarized as follows: Alkali production and more or less complete reduction of litmus occurred with all strains. With the exception of strains CXL, CXLI, CXLII, CXLIII, CXLVI, XVI, XXXIII, XXXVIII, L, LI, and LIV, alkali was produced promptly in the surface layer which soon cleared, changed to acid and became more or less green in color. The alkali layer diffused slowly downward, several well defined strata often being differentiated. Digestion proceeded slowly with the enumerated strains, and the medium gradually became more and more blue, changing to purple at the time digestion became evident.

8. *Gelatin colonies*.—A rather superficial examination of the colonies of all strains on gelatin showed that they were very much alike. Liquefaction occurred quickly in all strains except CXL, CXLI, CXLII, CXLIII, CXLVI, CXLVII, XVI, XXXIII, L, LI, and LIV. For complete description of the types of colonies, see detailed characteristics of individual strains, pages 567-568.

9. *Agar colonies*.—There were no essential differences between the agar colonies of the several strains. For description of types, see detailed characteristics of individual strains pages 568-570.

10. *Cohn's nutrient solution*.—This medium was made according to the following formula:

Distilled water,	1000. cc.
Di-potassium phosphate,	5. gr.
Magnesium sulphate,	5. "
Ammonium tartrate,	10. "
Potassium chlorid,	0.5 "

All strains were tried on this medium several times, but only two strains, LI and LIV, showed growth. These grew well with fluorescence, and the growth was accompanied by the formation of crystals of magnesium ammonium phosphate. The development was gradual but persistent, fluorescence and crystals

appearing in from 15 to 23 days. Those strains showing no growth were transferred to broth after twenty days. The transfers developed normally becoming fluorescent in two days.

11. *Uschinsky solution*.—The medium was prepared as follows:

Distilled water,	1000. cc.
Glycerin (Merck's Blue Label),	40. "
Sodium chlorid,	5. gr.
Calcium chlorid,	0.1 "
Magnesium sulphate,	0.4 "
Di-potassium phosphate,	2.2 "
Sodium asparaginate,	4. "

All strains except CXV developed well on this medium, showing strong fluorescence, and a viscid pellicle and sediment. Transfers made from tubes of CXV on Uschinsky solution developed well in broth.

12. *Nitrogen requirements*.—For determining the nitrogen requirements, a modified Uschinsky solution prepared as follows was used as a basal medium.

Distilled water,	1000. cc.	▲
Glycerin (Merck's Blue Label),	35. "	
Sodium chlorid,	6. gr.	
Calcium chlorid,	0.1 "	
Magnesium sulphate,	0.35 "	
Di-potassium phosphate,	2. "	

The mixture was warmed to secure complete solution and divided into three portions, one of which was reserved as a control while the others were treated respectively with 0.5% of c. p. urea and 1% of asparagin.

No growth, or only a slight trace, occurred in the control medium. The feeble trace of transient growth in a portion of the controls was attributed to the traces of nitrogen known to be present in the glycerin.

Upon the urea medium all showed good growth, except strain CXV which failed to develop. Transfers of this strain from the urea medium to broth developed promptly.

Eight strains developed with fluorescence upon the asparagin medium. These were as follows: CXXIX, CXXXIII, CXLVIII, CXLIX, CLIX, CLXXVII, 5 and LVI. Transfers to nutrient broth from the asparagin cultures of those strains which failed to grow developed promptly.

III. PHYSICAL AND BIOCHEMICAL FEATURES

1. *The action of the organisms upon dextrose, lactose, sucrose and glycerin.*—The carbohydrate and glycerin media were made by adding 2% of the sugars and 5% of glycerin respectively to bouillon which was sugar free as shown by the *B. coli* test. Cultures were observed for acid and gas production and for growth in the closed arm of the Smith tube.

Cultures and controls were analysed in duplicate for acid production after 1, 2, 4, 10, and 20 days incubation. Five cc. of the material were pipetted into 45 cc. of distilled water in Erlenmeyer flasks; $\frac{1}{2}$ cc. of 1% phenolphthalein solution was added and the mixture boiled 2 minutes and titrated hot with N/20 sodium hydroxid. Boiling often increased the amount of free acid, probably through the volatilization of ammonia formed simultaneously with the acid.

Control titrations were made upon bouillon cultures. Some acid was detected which is thought to have resulted from the decomposition of proteids, since muscle sugar was absent. The conclusions as to acid production which are indicated in the group number, pages 548 and 550, were drawn after comparing the results on the carbohydrate media with those on inoculated bouillon.

No gas was produced from the sugars or glycerin. Growth in the closed arms of the fermentation tubes was limited and occurred only in old cultures.

The detailed discussion of the characters on various carbohydrates follows:

Dextrose.—Acid production without gas evolution was characteristic. Two % dextrose litmus agar developed an acid

reaction in from 18 hours to 4 days. Two % dextrose bouillon in fermentation tubes, titrated hot with N/20 sodium hydroxid against phenolphthalein showed acid production, considerably more being present than in sugar free bouillon. (See tables 49, 50, 51). Previous to boiling, the acid was masked by the ammonia produced, the cultures became pink on addition of phenolphthalein but decolorized on boiling, with increased acidity.

Lactose.—Litmus milk showed an alkaline reaction, becoming doubtfully acid after several weeks. No acid, or a trace in a few cases, was found by titrating 2% lactose bouillon. (Tables 52, 53). By comparison most cultures in lactose bouillon were found to produce no more acid than the control cultures in sugar free bouillon.

Sucrose.—Same as lactose (table 54)

Glycerin.—Acid production without gas formation was observed with 11 strains on bouillon containing 5% of "Merck's Blue Label" glycerin. (See tables 55, 56).

The figures in the tables represent the percent of normal acid or alkali produced in the respective media and were calculated by subtracting the average reaction of duplicate controls from the average reaction of duplicate cultures, or vice versa.

TABLE 49. ACID AND ALKALI PRODUCED IN SUGAR FREE NUTRIENT BOUILLON
Test tubes, 10 cc.

Strain number	3 days		10 days	
	Acid	Alkali	Acid	Alkali
CXII,		0.30	0.06	
CXV,		0.09		
CXXVII,		0.16	0.04	
CXXVIII,	0.05		0.28	
CXXIX,	0.10		0.42	
CXXX,		0.02	0.26	
CXXXIII,			0.21	
CXXXIV,		0.21	0.15	
CXXXV,		0.36		0.22
CXXXVII,		0.31		0.12
CXXXVIII,		0.29		0.16
CXXXIX,		0.18		0.27
CXL,		0.35	0.36	
CXLI,		0.29		0.49
CXLII,		0.43		0.50
CXLIII,		0.25		0.62
CXLV,		0.03		0.94
CXLVI,		0.30	0.30	
CXLVII,		0.17		0.79
CXLVIII,	0.20			0.41
CXLIX,		0.21	0.48	
CL,		0.20		
CLI,		0.32		0.25
CLII,		0.35		0.49
CLIII,	0.03			0.55
CLIV,		0.14	0.16	
CLV,		0.14	0.07	
CLVI,		0.18		0.09
CLVIII,		0.13	0.34	
CLIX,		0.28	0.21	
CLXXVII,		0.33	0.03	
CLXXIX,		0.14		0.22
5,		0.18		0.25
XVI,		0.43		0.04
XXXIII,		0.14		0.51
XXXVI,		0.51		0.68
XXXVIII,		0.03		0.47
I,		0.36		0.36
I.I,		0.16		0.59
I.III,	0.44			0.72
I.IV,		0.11		0.11
I.VI,		0.01		0.74

TABLE 50. ACID AND ALKALI PRODUCED IN 2% DEXTROSE BOUILLON
Fermentation tubes

Strain number	1 day		2 days		4 days		10 days		20 days	
	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.
CXII,	1.36		2.15		2.36		2.20		1.50	
CXV,	0.00		0.48		0.59		0.48		0.70	
CXXVII,	1.16		1.53		1.44		1.20		1.10	
CXXVIII,	0.53		1.08		0.92		0.84		0.71	
CXXIX,	1.00		1.88		1.90		1.66		2.13	
CXXX,	0.78		0.92		0.96		0.65		1.19	
CXXXIII,	0.00		0.63		0.76		0.60		0.80	
CXXXIV,	0.00		0.56		0.60		0.08		0.13	
CXXXV,	0.38		0.32		0.38		1.72		0.63	
CXXXVII,	0.24		0.28		0.79		2.10		1.01	
CXXXVIII,		0.06	0.00		0.10		1.19		0.08	
CXXXIX,	0.48		0.51		0.43		1.72		0.62	
CXL,	1.21		1.40		1.42		2.63		1.38	
CXLI,	1.06		1.13		1.02		2.34		1.04	
CXLII,	1.01		1.20		0.97		2.27		1.13	
CXLIII,	1.31		1.39		1.55		2.67		1.35	
CXLV,	0.66		1.44		1.30		2.55		1.41	
CXLVI,	0.80		0.99		1.04		1.13		1.01	
CXLVII,	0.57		0.66		0.56		0.83		0.87	
CXLVIII,	0.73		1.28		1.41		1.55		1.89	
CXLIX,		0.14	0.35		1.24		2.08		2.31	
CL,	0.81		1.13		1.14		1.25		1.47	
CLI,	0.42		0.45		0.44		0.33		0.79	
CLII,	0.46		0.27		0.28		0.29		0.27	
CLIII,	0.22		0.46		0.94		1.25		1.13	
CLIV,	0.32		0.40		0.78		0.73		1.33	
CLV,	0.30				0.52		0.93		0.20	
CLVI,	0.30				0.38		0.60		0.40	
CLVIII,	0.35				0.60		1.07		0.55	
CLIX,	0.21				0.82		0.98			0.12
CLXXVII,	0.36				0.60		1.03		2.65	
CLXXIX,	0.34				0.65		0.91		1.10	
5	0.74				0.96		1.06		1.90	
XVI,	0.70				0.78		0.68		1.58	
XXXIII,	0.37				0.94		0.83		1.72	
XXXVI,	1.28				1.64		1.51		2.12	
XXXVIII,	0.05				0.70		0.71		1.66	
L,	0.31				0.40		0.39		1.10	
LI,		0.04			0.50		0.49		1.28	
LIII,	0.23				0.55		1.11		0.62	
LIV,	0.00				0.58		0.51		1.68	
LVI,	0.61				0.90		1.10		1.65	

TABLE 51. ACID AND ALKALI PRODUCED IN 2% DEXTROSE BOUILLON
Test tubes, 10 cc.

Strain number	1 day		2 days		4 days		10 days		20 days	
	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.
CXII,	0.41		0.44		0.89		1.76		3.13	
CXV,	0.03		0.21		0.28		0.71		0.75	
CXXXVII,	0.41		0.46		0.71		1.06		0.22	
CXXXVIII,	0.43		0.78		1.05		1.22		1.24	
CXXXIX,	0.48		0.55		1.54		2.23		2.50	
CXXX,	0.41		0.80		1.15		1.44		1.48	
CXXXIII,	0.10		0.17		0.37		0.85		1.06	
CXXXIV,	0.07		0.38		0.69		0.80		0.77	
CXXXV,	0.17		0.18		0.23		0.36		0.99	
CXXXVII,	0.10		0.16		0.29		1.08		1.16	
CXXXVIII,	0.03		0.16		0.43		0.54		0.94	
CXXXIX,	0.23		0.19		0.30		0.48		0.50	
CXL,	0.87		1.06		1.66		1.52		1.61	
CXLI,	0.58		0.81		1.13		1.35		1.71	
CXLII,	0.34		0.91		1.24		1.30		1.51	
CXLIII,	0.93		1.47		1.60		1.62		1.53	
CXLIV,	0.24		0.51		0.54		0.73		1.35	
CXLVI,	0.39		0.64		1.02		1.40		1.55	
CXLVII,	0.24		0.76		1.20		0.88		1.41	
CXLVIII,	0.36		0.62		1.40		3.26		6.06	
CXLIX,	0.26		0.98		1.50		2.32		2.44	
CL,	0.16		0.71		1.03		2.17		2.33	
CLI,	0.08		0.14		0.44		0.58		0.78	
CLII,	0.08		0.23		0.17		0.52		0.53	
CLIII,		0.06	0.16		0.36		0.65		1.23	
CLIV,	0.11		0.14		0.30		0.46		0.65	
CLV,	0.00		0.19		0.29		0.46		1.91	
CLVI,	0.00		0.18		0.25		0.55		0.83	
CLVII,	0.05		0.10		0.48		0.34		0.78	
CLIX,		0.05	0.30		0.54		0.96		0.98	
CLXXVII,	0.05		0.16		0.39		0.42		0.71	
CLXXIX,		0.04	0.31		0.55		0.92		1.32	
5,	0.19		0.85		1.14		0.95		1.63	
XVI,	0.22		0.59		1.01		0.73		1.15	
XXXIII,		0.06	0.33		0.45		0.67		1.17	
XXXVI,	0.18		0.87		0.79		1.10		1.71	
XXXVIII,			0.20		0.30		1.35		1.25	
L,	0.04		0.14		0.36		0.42		0.93	
LI,		0.04	0.32		0.88		0.78		0.94	
LII,	0.17		0.11		0.29		0.86		1.43	
LIV,		0.05	0.31		1.05		1.24		1.21	
LVI,	0.23		0.41		0.55		1.17		1.61	

TABLE 53. ACID AND ALKALI PRODUCED IN 2% LACTOSE BOUILLON
Test tubes, 12 cc.

Strain	1 day		2 days		4 days		10 days		20 days	
	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.
CXII,	0.12		0.27		0.35		0.12			
CXV,	0.12		0.11	0.15			0.28			
CXXXVII,	0.25		0.30		0.11		0.18			
CXXXVIII,	0.18		0.11		0.01		0.03			
CXXXIX,	0.21		0.03	0.17			0.35			
CXXX,	0.17		0.07	0.19			0.32			
CXXXIII,	0.20		0.07	0.21						
CXXXIV,	0.26		0.31	0.03						
CXXXV,	0.29		0.28		0.21					
CXXXVII,	0.26		0.32		0.35					
CXXXVIII,	0.34		0.35	0.08			0.22			
CXXXIX,	0.22		0.19		0.16	0.20				
CXL,	0.12		0.12		0.36		0.50			
CXLI,	0.14		0.23		0.40		0.43			
CXLII,	0.22		0.31		0.39		0.43			
CXLIII,	0.13		0.19		0.28		0.54			
CXLV,	0.18		0.20	0.11		0.31				
CXLVI,	0.11		0.13		0.35		0.32			
CXLVII,	0.24		0.26		0.34		0.53			
CXLVIII,	0.21		0.11	0.11		0.29				

TABLE 54. ACID AND ALKALI PRODUCED IN 2% SUCROSE BOUILLON
Test tubes, 10 cc.

Strain	1 day		2 days		4 days		10 days		20 days	
	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.
CXII,		0.12		0.40		0.18		0.21		0.31
CXV,		0.16		0.00	0.34		0.80		0.79	
CXXVII,		0.13		0.14			0.14			0.11
CXXVIII,		0.04		0.21				0.03		0.06
CXXIX,		0.01	0.05		0.37		0.82		0.09	
CXXX,		0.00			0.38			0.09	0.10	
CXXXIII,		0.16			0.37		0.52		0.06	
CXXXIV,		0.13		0.22	0.07		0.35		0.21	
CXXXV,		0.22		0.19	0.19		0.33		0.19	
CXXXVII,		0.19		0.18	0.24		0.52		0.04	
CXXXVIII,		0.28		0.30		0.14		0.10		0.11
CXXXIX,		0.26		0.22			0.27		0.24	
CXL,		0.10		0.18		0.32		0.56		0.41
CXLI,		0.11		0.27		0.32		0.12		0.59
CXLII,		0.16		0.34		0.36		0.66		0.43
CXLIII,		0.16		0.18		0.29		0.59		0.59
CXLV,		0.23		0.26	0.11		0.30			0.00
CXLVI,	0.04			0.21		0.48		0.52		0.72
CXLVII,		0.21		0.17		0.36		0.56		0.67
CXLVIII,		0.07	0.05		0.24		0.78			0.12
CXLIX,		0.11		0.05	0.12		0.14		0.14	
CL,		0.13		0.07			0.07			
CLI,		0.07		0.16		0.16		0.12		0.18
CLII,		0.17		0.16		0.17		0.03	0.08	
CLIII,		0.09	0.09		0.15		0.24		0.18	
CLIV,		0.08	0.01			0.03	0.44			
CLV,		0.04		0.01	0.14		0.21		0.15	
CLVI,		0.09		0.07		0.02	0.19			0.37
CLVIII,		0.13		0.14		0.31	0.07		0.06	
CLIX,		0.01	0.09		0.12		0.60			
CLXXVII,		0.17		0.21		0.28	0.58		0.70	
CLXXIX,		0.07	0.08		0.23			0.58		0.19
5,		0.11		0.06		0.10	0.05		0.14	
XVI,		0.07		0.26		0.41		0.69		0.68
XXXIII,		0.10		0.16		0.26		0.31		0.37
XXXVI,		0.12		0.02		0.06	0.97		1.20	
XXXVIII,	0.03		0.11		0.29		1.24		1.47	
L,		0.08		0.27		0.36		0.77		0.68
LI,	0.00	0.00		0.20		0.40		0.71		0.63
LIII,		0.07	0.07		0.40			0.79	0.13	
LIV,		0.02		0.21		0.31		0.72		0.72
LVI,		0.02		0.02		0.00		0.27		0.35

TABLE 55. ACID AND ALKALI PRODUCED IN 5% GLYCERIN DOUILLON
Test tubes, 10 cc.

Strain	1 day		2 days		4 days		10 days		19 days	
	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.
CXII,			0.00		0.25		1.35		1.56	
CXV,			0.00		0.29		0.56		0.53	
CXXVII,				0.06	0.00		0.62		0.94	
CXXVIII,				0.13	0.04		0.47		0.26	
CXXIX,			0.05		0.38		1.26		1.68	
CXXX,			0.00		0.29		0.68		0.56	
CXXXIII,			0.00		0.31		1.16		1.57	
CXXXIV,				0.02	0.14		0.73		0.65	
CXXXV,				0.15	0.07		0.39		1.10	
CXXXVII,				0.12	0.18		0.90		1.36	
CXXXVIII,				0.14		0.03	0.28		0.49	
CXXXIX,				0.00	0.20		1.16		1.06	
CXL,				0.21		0.45		0.37		0.42
CXLI,				0.26		0.39		0.29		0.14
CXLII,				0.24		0.37		0.46		0.55
CXLIII,				0.24		0.33		0.12		0.28
CXLV,				0.08	0.07		0.83		1.12	
CXLVI,				0.27		0.44		0.52		0.23
CXLVII,				0.19		0.22	0.29		0.22	
CXLVIII,			0.13		0.27		1.07		1.39	
CXLIX,			0.00		0.26		1.39		2.08	
CL,			0.03		0.54		1.43		1.05	
CLI,				0.18		0.07	0.43		0.77	
CLII,				0.13		0.04	0.19		0.33	
CLIII,				0.02	0.34		0.88		1.31	
CLIV,				0.00	0.16		0.70		0.96	
CLV,				0.12		0.05	0.19		0.37	
CLVI,			0.06		0.02		0.90		1.13	
CLVII,				0.12	0.11		0.49		0.67	
CLIX,			0.18		0.26		0.98		1.69	
CLXXVII,				0.19		0.20	0.19		0.34	
CLXXIX,			0.14		0.60		1.00		1.35	
5,						0.13	0.21		0.44	
XVI,						0.27		0.17	0.00	
XXXIII,						0.14	0.13			
XXXVI,						0.15	0.08		0.26	
XXXVIII,						0.20	0.51		0.52	
L,						0.29		0.32		0.16
LI,						0.16	0.23		0.32	
LIII,					0.28		0.95		1.06	
LIV,						0.28		0.09	0.05	
LVI,					0.27		1.38		1.81	

TABLE 56. ACID AND ALKALI PRODUCED IN 5% GLYCERIN BOUILLON
Duplicate trials Test tubes, 10 cc.

Strain	1 day		2 days		4 days		10 days		20 days	
	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.
CXII,					0.30		1.08			
CXV,					0.25		0.54			
CXXVII,					0.04		0.03			
CXXVIII,					0.06		0.34			
CXXIX,					0.34		0.86			
CXXX,					0.35		0.51			
CXXXIII,					0.25		0.67			
CXXXIV,					0.32		0.86			
CXXXV,						0.16	0.17			
CXXXVII,					0.14		0.44			
CXXXVIII,						0.05		0.02		
CXXXIX,					0.05		0.32			
CXL,						0.37		0.62		
CXLI,						0.45		0.62		
CXLII,						0.58		0.62		
CXLIII,						0.37		0.62		
CXLV,						0.08	0.14			
CXLVI,						0.45		0.57		
CXLVII,						0.49		0.43		
CXLVIII,						0.00	0.48			
CXLIX,					0.05		0.86			
CL,					0.25		0.58			
CLI,						0.20	0.37			
CLII,						0.20	0.11			
CLIII,					0.05		0.33			
CLIV,					0.26		0.26			
CLV,						0.08		0.02		
CLVI,						0.15	0.44			
CLVIII,						0.09	0.13			
CLIX,					0.18		0.47			
CLXXVII,						0.19		0.16		
CLXXIX,					0.30		0.89			
5,						0.30		0.20		
XVI,						0.43		0.56		
XXXIII,						0.18	0.20			
XXXVI,						0.19	0.08			
XXXVIII,						0.18	0.17			
L,						0.47		0.45		
LI,						0.15		0.15		
LIII,					0.14		0.59			
LIV,						0.35		0.46		
LVI,					0.60		1.23			

2. *Ammonia production*.—Ammonia was produced by all strains on nutrient broth, which is in accord with the statements of Thumm (31) (compare 20:754). The test was carried out as follows: For the first of the series 125 cc. portions of nutrient broth in Kjeldahl flasks were inoculated and incubated 10 days in the dark at room temperature (22° to 25° C.). At the end of this time determinations were made. Table 57 shows the ammonia content of cultures and control in cc. of N/10 hydrochloric acid equivalent for the 125 cc. and it is also calculated to a 100 cc. basis.

TABLE 57. AMMONIA PRODUCTION

Organism number	cc. N/10 HCl equivalent for 125 cc.	cc. N/10 HCl equivalent for 100 cc.
CXII,	33.0	26.4
CXV,	23.3	18.6
CXXXVII,	24.5	19.6
CXXXVIII,	28.9	23.1
CXXXIX,	45.6	36.5
CXXX,	31.2	25.0
CXXXIII,	54.7	43.8
CXXXIV,	57.8	46.2
CXXXV,	34.2	27.4
CXXXVII,	41.4	33.1
CXXXVIII,	34.8	27.8
CXXXIX,	43.2	34.6
CXL,	7.6	6.1
CXLI,	9.8	7.8
CXLII,	10.6	8.5
Control,	3.0	2.4

For the remainder of the series cultures were treated as before except that 100 cc. of media were used and the incubation period was 12 days at 20° C. The medium was identical with that of the preceding series.

TABLE 58. AMMONIA PRODUCTION

Organism number	cc. N/10 HCl equivalent for 100 cc.	Organism number	cc. N/10 HCl equivalent for 100 cc.
CXLIII,	13.0	CLXXVII,	23.5
CXLV,	43.8	CLXXIX,	46.3
CXLVI,	9.5	5,	33.3
CXLVII,	13.8	XVI,	11.6
CXLVIII,	39.4	XXXIII,	17.2
CXLIX,	22.5	XXXVI,	14.8
CL,	32.6	XXXVIII,	10.7
CLI,	22.2	L,	7.8
CLII,	14.2	LI,	7.7
CLIII,	48.1	LIII,	49.0
CLIV,	44.6	LIV,	9.8
CLV,	26.0	LVI,	63.5
CLVI,	39.1	CXII,	34.9
CLVIII,	44.7	CXV,	10.6
CLIX,	49.7		
Control,	2.5	Control,	3.4

3. *Action on nitrates.*—Nitrates in nitrate broth were reduced to nitrites by three strains, as indicated by the iodo-starch reaction (27:63). All cultures showed ammonia with Nessler's reagent; but this was thought to have been an end product of proteid decomposition rather than of nitrate reduction. No gas was produced.

Two formulas for nitrate broth were used with similar results.

- I. Distilled water1000. cc.
 Liebig's extract of meat..... 3. gr.
 Witte's peptone 10. gr.
 Potassium nitrate 3. gr.
- II. Distilled water1000. cc.
 Witte's peptone 1. gr.
 Potassium nitrate 2. gr.

Cultures in media of the first type were tested at the end of 10 days and 30 days. Only strain LI responded with a positive reaction at the first test, but strains LI, LIV, and XXXVI showed prompt blackening when tested after 30 days. The reaction was more rapid in media prepared by formula II and a positive reaction was obtained in 5 day old cultures of strains LI, LIV and XXXVI. Only these three strains showed the presence of nitrites at any time on either medium. The tests

were made repeatedly after incubation periods of various duration. The diphenylamine test for nitrates (32:340) gave a positive reaction on cultures of all strains except XXXVI. (Compare 19:152-154).

4. *Indol*.—Indol was not detected in broth cultures of any strain on the second or tenth day. The 10 cc. cultures were tested with ten drops of chemically pure sulphuric acid and one cc. of .02% sodium nitrite solution. No reaction appeared at the end of ten minutes or after warming. (3:33).

5. *Temperature relations*.—The optimum temperature for all strains was found to be in the neighborhood of 25° C. The thermal death point was approximately determined in the preliminary studies to lie between 49° and 55° C. The minimum temperature for growth was below 3° C. except for strain CXV which did not develop below 5° C. This strain showed growth at 37° C. All others failed to develop at that temperature and eighteen days exposure was fatal to them. Luxwolda (18) states that *B. fluorescens liquefaciens* develops remarkably fast at low temperature (3° to 5° C.).

6. *Acids and alkalies*.—A small amount of acid was produced in dextrose nutrient broth and indications of acid were also observed in nutrient broth containing lactose, sucrose, and glycerin. Titrations were made in hot solution with N/20 sodium hydroxid against phenolphthalein after 1, 2, 4, 10, and 20 days incubation. A trace of acid from proteid decomposition was observed with some of the strains in the sugar free bouillon series.

Hydrogen sulphid.—Tubes of nutrient broth were prepared in the usual way and, after inoculation, a strip of filter paper moistened with lead acetate solution was suspended above the culture in each tube. The paper in cultures of strain XVI began to blacken at five days showing hydrogen sulphid production. In ten days the papers in cultures of strains CXL, CXLI, CXLII, CXLIII, CXLVI, XVI, LIV, CXV, showed positive reactions, which in the cases of the last two strains,



PLATE XIII.—*Ps. fluorescens*. Types of gelatin colonies; liquefaction well under way. Figure 1. Strain LIII (three day old colony). Figure 2. Strain XXXVI (four day old colony). (See pages 567-568.) $\times 75$.

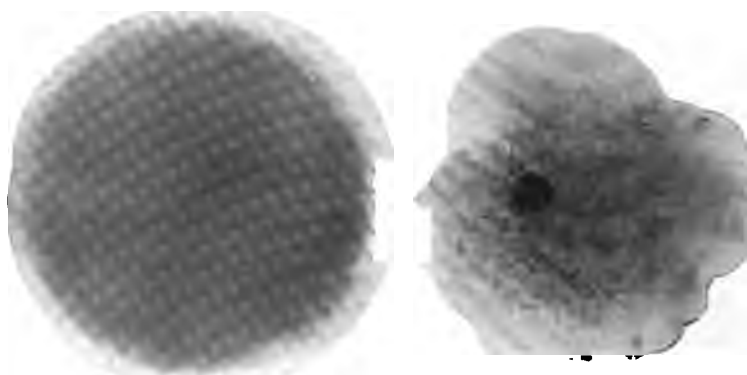
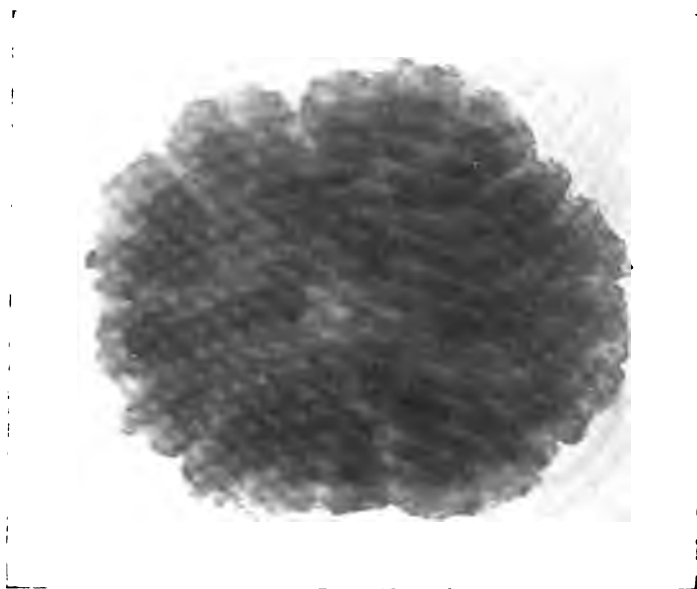


PLATE XIV.—*Ps. fluorescens*. Types of gelatin colonies. Figure 1. Strain XXX (two day old colonies). Figure 2. Strain L (two day old colonies). Figure 3. Strain LIII (two day old colonies). (See pages 567-568.) $\times 75$.

however, amounted to only a trace. After 19 days the papers in CXV, CXL, CXLI, CXLII, CXLIII, CXLVI, XVI, and L showed considerable blackening while those in LI, LIV and XXXVI showed but a trace. Test papers in the controls remained unchanged.

Ammonia was produced by all strains, see pp. 542, 543.

7. *Reduction processes*.—Litmus in litmus milk and in litmus agars was somewhat reduced by all strains. Nitrates were reduced to nitrites by three strains. (See action on nitrates, page 543).

8. *Odor*.—A putrefactive odor was associated with development on all the common media.

9. *Gas production*.—None observed by the Smith fermentation tube method in dextrose, lactose, sucrose, glycerin, or nitrate broths.

10. *Crystals*.—These were common in agar stab and plate cultures, and in gelatin plate cultures. Twinned crystals of magnesium ammonium phosphate were formed in Cohn's solution by strains LI and LIV.

11. *Oxygen requirements*.—Agar stab cultures were exposed to an atmosphere freed of oxygen by Buchner's pyrogalllic acid method (33). The tubes were placed in liter Novy jars containing 10 grams of dry pyrogalllic acid, to which 150 cc. of 1% sodium hydroxid solution was then added and the jars immediately sealed. These were opened at the end of two weeks incubation at room temperature. A barely visible surface colony and a slight growth along the puncture was apparent with all strains. The growth was limited and without fluorescence. While this property was apparent 24 hours later, its failure to develop in the oxygen free atmosphere might be attributed to the limited metabolism rather than to the absence of oxygen. Repeated trials yielded confirmatory results, but other methods (pages 588 and 589) have shown the organisms to be strictly aerobic. The slight growth obtained by the pyrogalllic acid method is attributed to the presence of small amounts

of unabsorbed oxygen during the first hours of the experiments.

12. *Fluorescence*.—The fluorescing property was possessed by the strains in varying degrees. Some were never observed to fluoresce with the intensity which was typical of others. The degree of fluorescence was also variable with the same strain upon different media. Strain CXV was never more than doubtfully fluorescent, but it was included in the studies for comparative purposes with the idea that its ability to fluoresce might be intensified by proper cultural methods. This result has not been obtained, however, and for this and other reasons it is probable that the organism in question should not be included with the fluorescent group.

The strongly fluorescent strains in general were the rapid liquefiers and digesters, and they produced more ammonia than the weakly fluorescent ones (c. f. chart page 551). Addition of ammonia or sodium hydroxid generally brought out a bright yellow-green fluorescence in all vigorous cultures deficient in this respect, with the exception of those of strain CXV (31). The pigment disappeared in all cultures if made slightly acid, only to reappear as soon as a slight excess of alkali was present. In general upon agar and broth a beautiful yellow-green fluorescence appeared in from three to five days. On gelatin, fluorescence developed only to a slight degree.

The green fluorescent pigment.—The most extended investigations concerning the pigment formed by the fluorescent bacteria have been made by Gessard (9), Thumm (31), and Jordan (14 and 15). Gessard concluded that *B. pyocyaneus* produces two pigments, pyocyanin and fluorescine. In order to bring out clearly the nature of the fluorescent pigment the papers of Thumm and Jordan (14) are quite extensively cited.

Thumm studied the following species:

B. fluorescens tenuis.

B. fluorescens putidus.

B. fluorescens albus.

B. fluorescens erythrosporus.

B. pyocyaneus (several strains)

Bact. syncyaneum.

B. viridans.

His results may be summarized as follows: All fluorescent bacteria show in alkaline gelatin, first a sky blue, later a moss green fluorescence and, accompanying the latter, a yellowing of the substratum. Old cultures with the exception of those of *B. fluorescens putridus* are orange-red with dark green fluorescence. All these colors are due to one yellow pigment. When an acid producer and a fluorescent organism are cultivated together the yellow pigment is formed normally, but there is no fluorescence. The green fluorescence in every case is caused by the action of the ammonia produced. Calcium chloride is unessential for the formation of the pigment, but magnesium sulphate and potassium phosphate are of the greatest importance. *Bact. syncyaneum* forms two pigments, a fluorescent one, and a steel-blue one.

Jordan (14) worked with the following species;

B. fluorescens albus.

B. fluorescens tenuis.

B. fluorescens mesentericus.

B. fluorescens putridus.

B. fluorescens liquefaciens.

B. viridans.

He summarizes his results as follows:

"Both sulphur and phosphorus are essential to pigment formation but the nature of the base associated with these elements is not important. Other things being equal the presence of the methyl or methylene group is coincident with superior nutritive value and fluorescigenic power. Acid in the medium not merely conceals the existence of the substance to which the color is due but interferes with those vital activities of the bacilli which in an alkaline medium lead to the production of that substance. An excess of substance favorable to growth and pigment formation checks the latter though the former may be

greater than before." Jordan believes that the fluorescent property is purely incidental. "When the medium contains certain compounds the metabolic activities of the organisms adjust themselves to these conditions and it is of no physiological significance that one of the products of this activity happens to be fluorescent."

13. *Diastasic action on potato starch.* A thin starch paste containing 2% thymol was added to equal volumes of ten day old broth cultures, the tubes placed in the thermostat for 8 hours, filtered and the filtrate tested with Fehling's solution. Sugar was detected in none of the cultures, indicating that diastase had not been formed.

14. *Group numbers.*—The characteristics of the several strains detailed above correspond as follows.

12 strains to the number, <i>Pseudomonas</i>	221.2332132
12 " " " " " "	221.2332133
7 " " " " " "	221.2322132
4 " " " " " "	221.2322133
2 " " " " " "	221.2333133
1 " " " " " "	221.2323132
2 " " " " " "	221.2222132
1 " " " " " "	221.2232133
1 " " " " " <i>Bacillus</i>	221.2222?32

However since there is no sharp line between acid production and no acid production from the sugars and glycerin, the only specific difference brought out by the group number is in regard to nitrate reduction. If gelatin cultures had been held only six weeks to determine liquefaction, the group number of strains CXL, CXLI, CXLII, CXLIII, CXLVI, XVI, and L, would have been 222.2332133 and of strains LI and I,IV 222.2333133. For the group number corresponding to the respective strains, see page 550.

15. *Separation of the 42 strains into groups.*—The 42 strains naturally separate themselves into 6 groups with respect to the following properties: the production of hydrogen sulphid, the reduction of nitrates to nitrites, growth upon asparagin Uschinsky solution, Cohn's nutrient solution, gelatin.

and milk. The separation of the strains into groups is shown in the chart on the following page, where the relation existing between ammonia production and fluorescence is also brought out. In general the strains producing comparatively small amounts of ammonia are the tardy liquefying and feebly fluorescent ones.

CHART SHOWING THE SEPARATION

Strain	Group number	Nitrogen from asparagin in		
		Hydrogen sulphid	Uschinsky solution	Nitrate reduction
CXXVII,	221.2332133	—	—	—
CXXVIII,	221.2332133	—	—	—
CXXX,	221.2332132	—	—	—
CXXXIV,	221.2332132	—	—	—
CXXXV,	221.2322133	—	—	—
CXXXVII,	221.2322132	—	—	—
CXXXVIII,	221.2332133	—	—	—
CXXXIX,	221.2322132	—	—	—
CXLV,	221.2222132	—	—	—
CL,	221.2332132	—	—	—
CLI,	221.2332132	—	—	—
CLIII,	221.2322132	—	—	—
CLIV,	221.2322132	—	—	—
CLV,	221.2332133	—	—	—
CLVI,	221.2322132	—	—	—
CLVIII,	221.2332133	—	—	—
CLXXIX,	221.2332132	—	—	—
XXXIII,	221.2332132	—	—	—
XXXVIII,	221.2322132	—	—	—
LIII,	221.2332132	—	—	—
CXII,	221.2332132	—	—	—
CXLVII,	221.2232133	—	—	—
CLII,	221.2332132	—	—	—
CXXIX,	221.2322133	—	+	—
CXXXIII,	221.2332132	—	+	—
CXLVIII,	221.2222132	—	+	—
CXLIX,	221.2332132	—	+	—
CLIX,	221.2322132	—	+	—
CLXXVII,	221.2322133	—	+	—
5,	221.2322133	—	+	—
LVI,	221.2332132	—	+	—
XXXVI,	221.2323132	±	—	+
LI,	221.2333133	±	—	+
LIV,	221.2333133	±	—	+
CXL,	221.2332133	+	—	—
CXLI,	221.2332133	+	—	—
CXLII,	221.2332133	+	—	—
CXLIII,	221.2332133	+	—	—
CXLVI,	221.2332133	+	+	—
XVI,	221.2332133	+	—	—
L,	221.2332133	+	—	—
CXV,	221.2222132	+	—	—

+, present; —, absent; ±, trace.

OF THE 42 STRAINS INTO GROUPS

Gelatin liquefaction begins in	Digestion of milk begins in	Ammonia in 100 cc. broth, 10-12 days, cc. N/10 HCl equivalent	Growth on Cohn's nutrient solution	Fluorescence
24 hrs.	10 d.	19.6	—	strong
16 hrs.	6 d.	23.1	—	"
16 hrs.	6 d.	25.0	—	"
16 hrs.	10 d.	46.2	—	"
24 hrs.	10 d.	27.4	—	"
24 hrs.	6 d.	33.1	—	"
62 hrs.	10 d.	27.8	—	"
24 hrs.	10 d.	34.6	—	"
24 hrs.	10 d.	43.8	—	"
16 hrs.	6 d.	32.6	—	"
40 hrs.	10 d.	22.2	—	"
16 hrs.	10 d.	48.1	—	"
16 hrs.	10 d.	44.6	—	"
20 hrs.	10 d.	26.0	—	"
16 hrs.	10 d.	39.1	—	"
16 hrs.	7 d.	44.7	—	"
20 hrs.	6 d.	46.3	—	"
40 hrs.	10 d.	17.2	—	moderate
16 hrs.	8 d.	10.7	—	feeble
16 hrs.	10 d.	49.0	—	strong
10 d.	10 d.	26.4	—	"
30 d.	30 d.	13.8	—	feeble
10 d.	10 d.	14.2	—	moderate
16 hrs.	10 d.	36.5	—	strong
16 hrs.	10 d.	43.8	—	"
16 hrs.	10 d.	39.4	—	"
16 hrs.	10 d.	22.5	—	"
20 hrs.	8 d.	49.7	—	"
24 hrs.	8 d.	23.5	—	"
20 hrs.	10 d.	33.3	—	"
16 hrs.	5 d.	63.5	—	"
24 hrs.	30 d.	14.8	—	feeble
50 d.	30 d.	7.7	+	"
50 d.	30 d.	9.8	+	"
5-6 mo.	3 mo.	7.6	—	feeble
5-6 mo.	3 mo.	9.8	—	"
5 mo.	3 mo.	10.6	—	"
4-5 mo.	3 mo.	13.0	—	"
5-6 mo.	3 mo.	9.5	—	"
4-5 mo.	40 d.	11.6	—	"
5 mo.	3 mo.	7.8	—	"
16 hrs.	10 d.	23.3	—	doubtful

COMPARATIVE STUDIES OF SEVEN REPRESENTATIVE STRAINS OF
GREEN FLUORESCENT SAP BACTERIA AND
SIX KNOWN SPECIES.

After having separated the 42 strains into groups in the preliminary studies as shown above, 7 representative strains were chosen for a more thorough study of their morphological, cultural, physical and biochemical features. The strains selected follow: From group one, strain CXLV, capsulated, and strain CXII, a slow liquefier, non-capsulated; from group two, strain CXLVIII a rapid liquefier, non-capsulated and, in contrast to the other groups, able to grow in asparagin Uschinsky solution; from group three, strain XXXVI, a nitrate reducer which does not grow on Cohn's solution; from group four, strain LI, a nitrate reducer which grows on Cohn's solution; from group five, strain CXL, a very tardy liquefier and casein digester, producing abundant hydrogen sulphid, but not reducing nitrates; from group six, strain CXV, a strong hydrogen sulphid producer, a rapid liquefier, growing at 37° C., Gram positive, and at most only doubtfully fluorescent. In addition, 6 strains of known species were introduced for comparative purposes. These are as follows:

<i>Ps. alba</i>	(Zimmermann)	Migula.
<i>Ps. fluorescens</i>	(Flügge)	"
<i>Ps. longa</i>	(Zimmermann)	"
<i>Ps. mesenterica</i>	(Tataroff)	"
<i>Ps. tenuis</i>	(Zimmermann)	"
<i>Ps. putrida</i>	(Flügge)	"

The first five cultures were obtained from Kral's Laboratory, while the culture of *Ps. putrida*, added to the station series some years ago, was supplied by Novy.

The 13 strains were rejuvenated by preliminary cultivation, while frequent replating assured the purity of the cultures. For methods and procedures see pages 525 and 526. The Society Card was used as a basis for the comparative studies and, in general, as in the preliminary studies, the methods em-

ployed were those recommended in "Standard Methods of Water Analysis."

DETAILED FEATURES

I. MORPHOLOGY

1. *Vegetative cells*.—Observations were made on 24 hour agar hanging block cultures and on hanging drop preparations from 16 to 24 hour agar slant condensation water. The cells of all strains were motile rods of medium length with rounded ends, occurring typically in chains of two; less frequently singly, or in chains of four or eight. Measurements were made of what appeared to be individual cells, but in some cases the figures given may represent double organisms. The limits of size which were obtained are best shown in tabular form:

TABLE 59. LIMITS OF SIZE ON HANGING BLOCK

Strain	Maximum		Minimum	
	Length	Diameter	Length	Diameter
<i>Ps. alba</i> ,	5.0 microns	1.2 microns	1.7 microns	0.7 microns
<i>Ps. fluorescens</i> ,	3.3 "	0.9 "	2.3 "	0.6 "
CXII,	4.7 "	1.0 "	2.0 "	0.6 "
CXV,	2.6 "	1.0 "	1.0 "	0.8 "
CXL,	2.3 "	0.9 "	1.0 "	0.5 "
CXLV,	4.0 "	0.7 "	1.5 "	0.6 "
CXLVIII,	4.0 "	0.6 "	1.4 "	0.4 "
XXXVI,	2.3 "	0.7 "	1.6 "	0.6 "
LI,	3.3 "	0.7 "	1.7 "	0.5 "

TABLE 60. LIMITS OF SIZE ON HANGING DROPS

Strain	Maximum		Minimum	
	Length	Diameter	Length	Diameter
<i>Ps. alba</i> ,	2.5 microns	0.8 microns	1.25 microns	0.5 microns
<i>Ps. fluorescens</i> ,	3.0 "	0.8 "	1.18 "	0.6 "
<i>Ps. longa</i> ,	2.2 "	0.7 "	1.0 "	0.6 "
<i>Ps. mesenterica</i> ,	1.6 "	0.8 "	1.05 "	0.6 "
<i>Ps. tenuis</i> ,	1.9 "	0.8 "	1.05 "	0.5 "
<i>Ps. putrida</i> ,	1.1 "	0.7 "	0.9 "	0.5 "
CXII,	1.5 "	0.6 "	0.9 "	0.5 "
CXV,	4.0 "	0.9 "	1.6 "	0.5 "
CXL,	2.3 "	0.9 "	1.0 "	0.5 "
CXLV,	3.0 "	0.8 "	0.9 "	0.5 "
CXLVIII,	3.8 "	0.8 "	1.5 "	0.5 "
XXXVI,	1.5 "	0.7 "	0.7 "	0.5 "
LI,	3.0 "	0.8 "	1.2 "	0.6 "

Measurements upon preparations from 24 hour agar slants stained two minutes with carbol fuchsin without heating yielded the following results.

TABLE 61. LIMITS OF SIZE ON STAINED PREPARATIONS

Strain	Maximum		Minimum	
	Length	Diameter	Length	Diameter
<i>Ps. alba</i> ,	2.8 microns	0.7 microns	1.1 microns	0.4 microns
<i>Ps. fluorescens</i> ,	2.1 "	0.5 "	1.1 "	0.4 "
<i>Ps. longa</i> ,	1.9 "	0.7 "	1.3 "	0.5 "
<i>Ps. mesenterica</i> ,	1.7 "	0.7 "	0.9 "	0.5 "
<i>Ps. tenuis</i> ,	2.5 "	0.8 "	1.7 "	0.5 "
<i>Ps. putrida</i> ,	1.4 "	0.7 "	0.9 "	0.5 "
CXII,	2.2 "	0.6 "	1.2 "	0.5 "
CXV,	2.0 "	0.8 "	0.8 "	0.5 "
CXL,	1.4 "	1.0 "	0.7 "	0.5 "
CXLV,	3.2 "	0.7 "	1.0 "	0.5 "
CXLVIII,	2.7 "	0.7 "	1.8 "	0.6 "
XXXVI,	1.8 "	0.6 "	1.1 "	0.5 "
LI,	1.5 "	0.6 "	1.1 "	0.5 "

Flügge (6:292) states that *B. fluorescens liquefaciens* is .3-.5 microns in diameter and 1-2 microns in length. According to Migula (21:886) *Ps. fluorescens* has the following dimensions: diameter .68 microns; length 1.17-1.86 microns; Chester (3:323) gives the following: 1-1.5 microns in length by .5 microns in diameter. Ellis (5:108) gives the length of the rods from 1.5-6 microns and the diameter .4 microns. Zimmermann (34:16) gives the following measurements for *B. fluorescens tenuis*. Length 1-1.85 microns; thickness approximately .8 microns.

2. *Endospores*.—No indication of endospores was observed in any strain. The various spore stains which were tried failed to show anything further than polar bodies or granulation of rods. Zimmermann notes the presence of polar granules in *B. fluorescens tenuis* (34:16).

3. *Flagella*.—Flagella preparations were made only upon the sap bacteria. From 1 to 6 polar flagella were easily demonstrated upon each strain except CXV. (See Plate X, figures 5 and 6). Preparations were made from 16 to 24 hour agar

slants by means of Loeffler's method (with anilin gentian violet) or by Löwit's modification of the same. The arrangement of the flagella of the several strains was as follows.

Strain CXII.—A polar tuft of 3 flagella at one end of a chain of two cells was typical. Occasionally tufts of 1 to 6 flagella occurred at both ends of double cells.

Strain CXV.—This strain had peritrichiate flagella. Tufts were common at each end of chains. Lateral flagella were common on single cells (c. f. Plate X, figure 2).

Strain CXL.—The flagella typically occurred in a polar tuft at one end of the double cells, frequently at both ends.

Strain CXLV.—Tufts of flagella were demonstrated on one end of double cells, and occasionally on both ends. Single organisms usually had one polar flagellum.

Strain CXLVIII.—Double cells commonly had 1 or 3 flagella at one end; occasionally 1 at each end. Single cells with 2 polar flagella were not uncommon.

Strain XXXVI.—The double cells had 1, 3, or 6 polar flagella, most commonly a tuft of 3; occasionally the flagella occurred at both ends of the double cells.

Strain LI.—Most commonly 2 flagella occurred at one end of the chains of two cells and 3 at the other, or 1 at one end and 1 to 6 at the other. Double cells with 1 to 6 flagella at one end were common.

4. *Capsules.*—Only the fluorescent sap bacteria were examined for capsules. Such an envelope was demonstrated upon strains CXV and CXLV and upon strain XXXIII as previously noted (page 528). A suggestion of capsulation was noted on flagella preparations of strain CXLVIII, but the results with the contrast capsule stain were negative. Cultures of strain XXXVI on 2% sucrose peptone solution were very stringy.

Strain CXV.—Capsules were easily demonstrated upon preparations from 10 day broth cultures by either Welch's method or by Richard Muir's contrast stain (22:106). Fre-

quently 2 and sometimes as many as 5 cells occurred side by side in the same capsule, with flagella arising about the periphery of the envelope (c. f. Plate X, figure 3).

Measurements obtained on the capsule preparations follow:

Length of cell	Diameter of cell	Length of capsule	Diameter of capsule
1.6 microns	0.53 microns	2.18 microns	1.57 microns
1.8 "	0.53 "	2.50 "	1.57 "
1.8 "	0.50 "	2.80 "	1.82 "

Strain CXLV.—Material from 10 day broth cultures was stained by Richard Muir's method and capsulation demonstrated. Parallelism of cells within the capsules was absent with this strain.

5. *Zoogloea*.—Not observed.

6. *Involution forms*.—Unusually long cells were common in old cultures.

7. *Staining reactions*.

Gram's stain.—Films from 4 day agar colonies of the 13 strains were stained as follows: (22:103).

Treated with anilin gentian violet (22:101) 1½ minutes, washed in water; treated with Gram's solution 1½ minutes, and immersed in absolute alcohol 4 minutes. All of the fluorescent organisms were Gram negative (21:888). All strains except *Ps. alba* showed some granular spots which failed to decolorize in 4 minutes. Strain CXV remained deeply stained even after 15 minutes in absolute alcohol.

Gram's stain with amyl alcohol (29:108).—Films of strains CXII, CXV, and CXL were stained as above, but amyl alcohol was used 5 minutes for decolorizing. Strain CXII retained the stain faintly, some cells more than others, and a bi-polar effect was noticeable. With CXV the stain was irregularly retained, the cells having a granular appearance. Cells of strain CXL were only partially decolorized even after 15 minutes exposure to amyl alcohol.

Aqueous fuchsin.—Aqueous fuchsin was prepared by dissolving one gram of Grüber's fuchsin in 10 cc. of water. Films from 4 day agar colonies of the 13 strains were treated with this stain for two minutes and washed in water. The films were mounted in water and microscopic examinations made. The cells of *Ps. fluorescens*, *Ps. longa*, *Ps. tenuis*, CXV, CXL, and LI were deeply stained: while those of *Ps. alba*, *Ps. mesenterica*, *Ps. putrida*, CXII, CXLV, CXLVIII, and XXXVI were only faintly stained. The cells from all strains except CXV presented a granular plasmolysed appearance and with strains *Ps. tenuis* and CXL a bi-polar staining was common.

Aqueous gentian violet.—The stain was prepared by dissolving 1 gram of Grüber's gentian violet in 10 cc. of water. Preparations from 4 day agar colonies were stained 2 minutes and washed in water. The cells of *Ps. alba*, *Ps. longa*, CXV, CXL, CXLV, CXLVIII, and LI were well stained, while those of *Ps. fluorescens*, *Ps. tenuis*, *Ps. mesenterica*, *Ps. putrida*, XXXVI, and CXII were rather faintly stained. Plasmolysis occurred with all strains but was particularly noticeable in the following: *Ps. fluorescens*, *Ps. longa*, *Ps. tenuis*, *Ps. putrida*, and CXII.

Carbol fuchsin (Ziehl).—Films were prepared from 4 day agar colonies of all strains, stained two minutes with Ziehl's carbol fuchsin and rinsed with water. Strain CXV was the only organism in which the entire cell was stained. Cells of *Ps. alba*, *Ps. fluorescens*, *Ps. longa*, *Ps. putrida* were only faintly stained, while those of *Ps. mesenterica*, *Ps. tenuis*, CXII, CXL, CXLV, CXLVIII, XXXVI, and LI were fairly well stained but showed a bi-polar effect. Chains of cells of the latter two mentioned strains presented a barred appearance.

II. CULTURAL FEATURES

1. *Agar stroke*.—On agar stroke the thirteen strains displayed similar growth characters, indeed no specific constant difference can be pointed out. The line of inoculation first ap-

peared in 24 hours, as a faint white streak, rapidly becoming beaded above, moist, glistening and of slimy consistency. It had a white to light grayish color and often appeared nacreous in certain lights. The medium became more or less green fluorescent on the third day, the coloration gradually increasing in intensity. Strain CXV grew more slowly than the others and with doubtful fluorescence.

2. *Potato slants*.—Cylinders were cut from large tubers and divided so as to give a slant surface. These were washed for several hours in flowing tap water before they were placed in the tubes containing a few drops of distilled water. Sterilization was accomplished by the intermittent method.

Upon this medium a moderate growth occurred with all strains. At first in about twenty-four hours a very delicate whitish accumulation could just be distinguished. This developed slowly into a light brown, slimy, smooth, filiform, spreading band, later becoming thick and darker brown, sometimes even chocolate brown in old cultures. Strain CXV was characterized frequently by a more or less corrugated to rhizoid, slimy growth, moist at first, later appearing rather dry. The medium was more or less grayed by all strains. Strong greening of the substratum was present with some strains but not constantly. This reaction was observed with the following strains; CXII, in 31 days: CXLV, CXLVIII, LI in 5 days; *Ps. fluorescens* in 3 days.

3. *Loeffler's blood serum*.—This medium was not employed.

4. *Agar stab*.—Specific differential characters were not found on this medium. The surface growth was moderate with all 13 strains, at first white, becoming more or less brown, round and entire to contoured with toothed edge. The puncture growth which was at first beaded to filiform became echinate to villous, the latter character being typical of old cultures. The best development occurred in the upper portion of the stab. The medium was at first blue-green fluorescent, becoming more

and more yellow-green. In the old cultures the agar had assumed a brownish to amber color. Fluorescence was not as strongly evidenced by some strains as by others. The strongly fluorescent strains were: *Ps. fluorescens*, CXLVIII, CXII, CXLV, *Ps. mesenterica*, CXL, *Ps. tenuis* and LI named approximately in the order of their fluorescing powers. *Ps. alba*, *Ps. longa*, *Ps. putrida*, and XXXVI showed moderate fluorescence. Strain CXV was at most doubtfully fluorescent.

5. *Gelatin stab at 20° C.*—Gelatin media were prepared with "Nelson's Photographic Gelatin No. 1," and a "Gold Label" gelatin. Sometimes 10 and sometimes 12% were employed. Neither the percent of gelatin nor the brand was observed to have any significant effect on the cultural characters. On gelatin media there were two types among the 13 strains, a liquefying and a non-liquefying type, the latter including two very tardy liquefiers. However, a sharp division line between types does not exist.

Liquefying type.—To this group belong *Ps. fluorescens*, *Ps. mesenterica*, CXII, CXV, CXLV, CXLVIII, and XXXVI.

Ps. fluorescens.—In 18 hours a slight growth appeared as a filiform whitish line. Crateriform liquefaction began in two days gradually extending the shallow crater until the liquefaction assumed a stratiform type. The fluid was at first yellowish white and moderately turbid, the stab being filiform and finely villous above, beaded and finely villous below. A slight green fluorescence was apparent, but only in the liquid portions. The fluorescence in gelatin, +10 Fuller's scale, was never as marked as in agar of the same reaction. The influence of the reaction upon fluorescence is apparent from the results of two series of gelatin cultures, one of which had an initial reaction of -4.7 Fuller's scale and the other of -12. The fluorescence appeared earlier and became noticeably more intense in the more alkaline medium, showing that a slightly alkaline gelatin is more favorable to the development of fluorescence than a neutral or acid one. This is in accord with the statements of Thumm (31) and Jor-

dan (14). During the incubation the alkali was partly neutralized by the carbon dioxide absorbed from the air. The actual reaction at the time the notes were taken was determined by titrating control tubes with N/20 sodium hydroxide and phenolphthalein. The medium originally reacting at -4.7 Fuller's scale had an actual reaction of $+2.4$; that originally reacting at -12.4 had an actual reaction of -6.1 . Fluorescence had not appeared in 26 days in the medium having an original reaction of -4.7 , but in the medium having an original reaction of -12.4 fluorescence was as marked as in agar cultures. The actual reaction of the more alkaline medium at this time was $+2.7$ Fuller's scale. Liquefaction has proceeded farther in this medium than in the other, which now had a reaction of $+4.4$ Fuller's scale.

Gelatin liquefaction proceeded slowly and was completed in 45 days, at which time the fluid was rather clear and of an olive green color. Considerable white flaky precipitate was thrown down as liquefaction proceeded and a scum usually appeared. There was a slight development in the line of puncture, liquefaction occasionally appearing as a tunnel or as beaded spots along the stab.

Ps. mesenterica.—In 1 or 2 days the growth appeared as a white line, filiform above and beaded below. The colony was white with depressed center and irregularly dentate edge, occasionally round with entire edge. Crateriform liquefaction usually began in from 8 to 17 days, but was occasionally delayed until about a month had elapsed. The liquefaction gradually became stratiform and was practically completed in about 4 months. A somewhat more rapid liquefaction and stronger fluorescence occurred in alkaline gelatin; however traces of green fluorescence could be detected occasionally in gelatin reacting $+10$ Fuller's scale.

Strain CXII.—At the outset of these studies this organism first began gelatin liquefaction in about 10 days; at their close, after an interval of two years, gelatin liquefaction constantly appeared in 24 hours. In one to two days the growth was a

white filiform line which gradually became echinate to villous. Liquefaction proceeded from crateriform to stratiform and was completed in about one month. Fluorescence was rarely seen in +10 gelatin but appeared in alkaline gelatin (compare with *Ps. mesenterica* and *Ps. fluorescens* pages 559, 560). An abundant white flaky precipitate settled out as liquefaction proceeded. Growth in the puncture was transient, the line of inoculation remaining about the same.

Strain CXV.—Growth appeared in a few hours, the puncture being beaded, liquefaction becoming evident in 16 hours. The colony sank in a saucer-like depression, the liquefaction soon becoming stratiform, proceeding quite rapidly at first but gradually slowing down when nearly all the 7 cc. of medium had been liquefied. The line of puncture quite frequently showed considerable liquefaction. The fluid was slightly turbid but developed neither yellow nor green color. A thin surface membrane developed and a moderate amount of white precipitate was thrown down. Liquefaction of the 7 cc. of medium was completed in about a month's time.

Strain CXLV.—This organism at the beginning of the studies was one of the most rapid liquefiers, commencing liquefaction in 24 hours and completing it in 27 days; but in the course of 18 months' cultivation it has gradually lost its ability to liquefy gelatin reacting +10 Fuller's scale. Otherwise it does not differ essentially from strain CXII. In the studies with alkaline gelatin media with original reactions of -4.7 and -12.4 Fuller's scale, this organism showed crateriform liquefaction in 26 days in the -12.4 medium and none in the -4.7 medium. At this time the -12.4 medium had a reaction of +2.7 Fuller's scale. It is thus evident that this organism retained the power to liquefy alkaline or very slightly acid gelatin, after it had practically lost its ability to liquefy the ordinary gelatin. Fluorescence occurred only in the alkaline gelatin.

Strain CXLVIII.—This organism resembled *Ps. fluorescens* very closely on gelatin stab, but in old cultures it did not show

the olive green color noted with the latter organism. No other points of difference were observed.

Strain XXXVI.—This strain could not be distinguished from *Ps. fluorescens* or strain CXLVIII, except by a more feeble fluorescence on alkaline gelatin.

Strain LI.—This organism also resembled *Ps. fluorescens* closely. It could be distinguished only by the fact that liquefaction was delayed, first appearing in about 50 days. LI is evidently a strain of *Ps. fluorescens*, tending toward the variety *non-liquefaciens*.

The non-liquefying type.—To this group belong the following organisms: *Ps. putrida*, *Ps. alba*, *Ps. longa*. Strains *Ps. tenuis* and CXL are classified here provisionally since liquefaction is long delayed. Cultures were held under observation for six months in a moist chamber at 18° to 20° C.

Ps. putrida.—Growth was slow, becoming visible the fourth day; the stab was filiform above and beaded below with a small white colony at the surface. At 12 days the colony was round and brownish, the surface being somewhat contoured. At 20 days the colony had become chocolate brown at the center, and the edge showed spiny outgrowths. In from 20 to 40 days the medium showed a strong browning, beginning at the surface and progressing slowly downward. No liquefaction was observed in five months. At this time the colony was round, about 1 cm. in diameter, having a reddish-brown center and raised edge with rhizoid and spiny processes; the puncture was beaded and villous.

Ps. alba and *Ps. longa.*—Cultures were similar to those of *Ps. putrida*, but no browning of the colony or of the medium was apparent. In 5 months the following characters were in evidence; colony, white, round with beaded to lacerate edge; puncture, beaded and widely villous in the upper portions; no liquefaction.

Ps. tenuis.—Young cultures were not essentially different from those of *Ps. alba* and *Ps. putrida*. Some colonies were round and entire, while others were erose. The stab was filiform

to beaded, becoming villous later. Liquefaction constantly began after about 4 months and proceeded slowly, the fluid being thick and slimy. At this time the stab was a faint white filiform line, development in this portion of the culture having ceased. According to Migula's classification *Ps. tenuis* is a non-liquefier. (21:910).

Strain CXL.—Cultures of this organism were like those of *Ps. tenuis*. Liquefaction constantly began after about 5 months' incubation. At this time the stab was either filiform and beaded, or filiform, beaded, and widely villous. As in the cultures of *Ps. tenuis* the liquid was quite thick and slimy. The purity of the culture and its identity with the original strain was proved. It is worthy of note that this organism, when held at 25° C., peptonized milk only after three months' incubation.

6. *Nutrient broth*.—Upon this medium slight differences were observed among the different strains. Moderate clouding appeared in 18 to 24 hours in all except CXV, which was rather tardy in showing growth in most liquid media. The medium rapidly became more or less turbid, forming a scum or pellicle which at intervals settled to the bottom of the tube as a white flaky to viscid precipitate. A rather tough membranous pellicle was produced by strain CXLV. More or less blue-green fluorescence was apparent in from 3 to 10 days, but was never strong in *Ps. longa*, *Ps. tenuis*, *Ps. putrida* or XXXVI, except in alkaline broth. Strain CXV produced only a trace of fluorescence. The other strains usually showed beautiful green fluorescence, but it was not constantly present. The blue-green rapidly became yellow-green and in old cultures the medium cleared and showed an amber yellow color. Cultures of CXV and CXLV often became quite stringy.

Strain CXV.—A slight to moderate clouding appeared in from 2 to 5 days, gradually increasing in intensity. Later the cultures developed a white surface membrane, the substratum becoming quite clear. An abundant white precipitate was thrown down. Old cultures became amber colored.

7. *Milk*.—The medium consisted of fresh centrifuged milk, titrated, filtered, and tubed, 10 cc. per tube. Sterilization was effected by the intermittent method.

Acid production.—Triplicate titrations of cultures and controls were made after 1, 2, 4, 10, 20, and 46 days' incubation. Five cc. of cultures and controls respectively were pipetted into 45 cc. of distilled water in Erlenmeyer flasks, 0.5 cc. of 1-100 phenolphthalein added, the mixture boiled 2 minutes and titrated hot with N/20 sodium hydroxid. The averages of the three titrations of cultures were compared with the averages of those of the three control tubes, in order to obtain the percent of normal acid or alkali produced at each time. The results obtained were as follows:

TABLE 62. ACID PRODUCTION IN MILK

Strain	1 day		2 days		4 days		10 days		20 days	
	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.
<i>Ps. alba</i> ,		0.02		0.15		0.54		0.89		0.93
<i>Ps. fluorescens</i> ,		0.07	0.13		0.46		1.76		3.77	
<i>Ps. longa</i> ,		0.22		0.50		0.62		1.10		1.14
<i>Ps. mesent'a</i> ,	0.00	0.00		0.30		0.69		0.87		1.11
<i>Ps. tenuis</i> ,		0.26		0.31		0.46		0.75		0.83
<i>Ps. putrida</i> ,		0.12	0.05			0.03		0.29	0.04	
CXII,		0.20	0.81		1.28		2.80		3.45	
CXV,	0.03		0.05		0.13		0.54		1.20	
CXL,		0.04	0.08			0.10		0.38		0.72
CXLV,		0.29		0.28		0.48		0.44		0.90
CXLVIII,		0.06	0.78		1.46		2.42		3.70	
XXXVI,		0.20		0.28		0.44		0.17	0.74	
LI,		0.03		0.21		0.22		0.56		0.91

Strain	20 days		46 days	
	Acid.	Alk.	Acid	Alk.
<i>Ps. alba</i>		1.15		1.20
<i>Ps. fluorescens</i> ,	5.29		4.41	
<i>Ps. longa</i> ,		1.03		1.22
<i>Ps. mesenterica</i> ,		1.19		1.22
<i>Ps. tenuis</i> ,		0.99		0.72
<i>Ps. putrida</i> ,		0.06	0.29	
CXII,	3.54		4.29	
CXV,	1.82		3.85	
CXL,		0.62		0.87
CXLV,		0.45		0.12
CXLVIII,	5.31		3.46	
XXXVI,	0.72		2.20	
LI,		0.57		1.22

There were 2 types among the 13 strains according to their action on milk. One type produced considerable acid and coagulated and digested the medium quite rapidly, a more or less greenish color being present. The coagulum was of a more or less jelly-like consistency. The other type showed clearing without coagulation of the milk, the action being delayed and taking place very slowly. With certain strains digestion was not evident until about the third month. To the first group belong the following strains: *Ps. fluorescens*, CXII, CXV, CXLVIII, and XXXVI; and to the second group belong: *Ps. alba*, *Ps. longa*, *Ps. mesenterica*, *Ps. tenuis*, *Ps. putrida*, CXL, CXLV, and LI.

Strains *Ps. fluorescens*, CXII, and CXLVIII of the first type, behaved similarly on milk. A more or less jelly-like coagulation appeared in from 2 to 10 days coincident with acid production. The coagulum formed was rather slimy with the first organism named but with the others was quite firm. Digestion with more or less greenish discoloration of the peptonized portion was apparent in 4 days, becoming complete in from 18 to 30 days, the cultures at this time being relatively clear and closely resembling broth cultures of similar age. A deep green color appeared at the surface in these old cultures and upon agitation the whole medium became olive green. The coloration was more pronounced in *Ps. fluorescens* than in the other two. Luxwolda (18) states that *B. fluorescens liquefaciens* first coagulates milk with a lab ferment and then peptonizes it.

Strain XXXVI differed from the three preceding organisms in that only a trace of green color was present. Coagulation with this strain was always of jelly-like consistency.

Strain CXV showed clearing without coagulation until about the eighteenth day when a firm coagulum appeared coincident with acid production. Digestion continued and was completed in from 30 to 104 days. The medium never appeared green but was more or less straw colored throughout.

With the eight strains of the second type the medium remained practically unchanged in appearance from 10 to 85 days.

the only change which could be noted being its scarcely perceptible browning or greening. Clearing without coagulation occurred sooner or later with all strains, and was complete in from 1 to 5 months' time. Cultures of strain CXL in particular could not be distinguished from the control tubes until about 3 months after inoculation, when clearing without coagulation began to be apparent. This reaction was completed in from 4 to 5 months. Repeated trials with recovery of the organism showed that this clearing of the medium was not due to contamination. (Compare action of this organism on milk with its action on gelatin). The only evidence of growth with strains *Ps. longa*, *Ps. mesenterica*, and *Ps. putrida* until after a month had elapsed, was a scarcely perceptible browning of the medium and a thin scum.

8. *Litmus milk*.—To freshly centrifuged milk with a reaction of +10 to +12 Fuller's scale was added 2% of a saturated aqueous solution of Merck's chemically pure blue litmus; the medium was then filtered, tubed and sterilized by the intermittent method. When ready for use the milk had a rich lavender color.

On this medium all strains developed an alkaline reaction, which, when digestion commenced, was succeeded by one of an acid character. The groups already referred to on gelatin and milk were likewise differentiated here.

The first group, rapid liquefiers and rapid digesters, showed an alkaline reaction at the outset which soon gave place to an acid reaction when digestion commenced. As digestion proceeded, a purple to a reddish coloration advanced into the substratum, the latter becoming first blue, then purple and red, finally bleaching to a straw or amber color when digestion was complete. The surface layers were more or less greenish, especially with *Ps. fluorescens*, CXII, CXLVIII. Upon agitation of the tubes when digestion was completed, the medium became olive green throughout. To this first group belong *Ps. fluorescens*, CXII, CXV, CXLVIII, and XXXVI. *Ps. mesenterica* on this medium reacts more like the second group.

The second group, non-liquefiers, (and very tardy liquefiers and digesters), comprises the following strains: *Ps. alba*, *Ps. longa*, *Ps. putrida*, *Ps. tenuis*, CXL, LI and *Ps. mesenterica*. Alkalinity was apparent the second day, except with *Ps. putrida*; it first manifested this reaction on the tenth day. Alkalinity gradually increased at first in cultures of this group, and after some time acidity developed simultaneously with digestion. After several months, when digestion was nearly complete, cultures of all strains except CXL and *Ps. putrida* were colored purple throughout, without perceptible clearing. Cultures of CXL were pink throughout, but otherwise resembled *Ps. putrida*.

The action of all 13 strains on litmus milk was essentially the same; first, alkali production, then acid production accompanied by digestion.

9. *Gelatin colonics*.—The colony of strain CXLVIII is described as the type of the rapidly liquefying group.

Macroscopically; at first punctiform to round, yellowish, raised, smooth, glistening, and entire, soon liquefying and sinking in saucer-like depressions, the fluid showing slight green fluorescence. Microscopically; round, entire, convex, brownish, center dark and surrounded by a thinner zone (liquid). Internally granular to grumose with spiny processes about the edge. The filaments were variously oriented, being more loosely intertwined at the edge where they extended out into the liquid portion. The colonies soon disintegrated, becoming floccose or grumose masses in the liquefied gelatin. (See Plate XII-XIV).

Ps. fluorescens and strains CXII and CXLV could not be distinguished specifically from CXLVIII.

Strain CXV.—This strain closely resembles the type. Radiate filaments were frequently present, often being almost perfectly symmetrical, the ends of the filaments forming the bordering fringe of the colonies. Liquefaction was very rapid.

Strain XXXVI.—At first round, entire, yellowish brown, finely granular discs, sometimes with an irregular cracked appearance. Some were undulately zoned and the surface irregularly

marked with curved lines. The internal structure became grumose, to broken and fimbriate. A slow and somewhat delayed liquefaction began as a finely granular outer zone, the appearance thereafter conforming to the type, CXLVIII.

Ps. alba is described as the type of the non-liquefying and tardy liquefying group. Macroscopically; punctiform, raised, smooth, yellowish. Microscopically; roundish, entire to broken, yellow-brown, somewhat gray towards the edge. Internally grumose to fluccose. *Ps. putrida*; slower growth than *Ps. alba*; macroscopically like the latter. Microscopically; round, entire, brownish, granular. The surface was slightly ridged and furrowed giving a shadowy appearance to the colony. Later the colonies became grumose to broken and were dark brown in color.

Ps. tenuis.—Macroscopically; like *Ps. alba*. Microscopically; roundish, granular to grumose or floccose, becoming spiny or fimbriate.

Strain CXL.—Macroscopically; like *Ps. alba*. Microscopically; much like the type, being round, convex, entire, yellowish-brown, and granular toward the center, the edge being thicker and somewhat grayish. Others were yellow-brown throughout; larger ones were often roundish with undulate edge. Young colonies were perfectly round, finely granular, brownish discs, with sharply defined edge.

Strain LI.—Macroscopically; like *Ps. alba*. Microscopically; round, entire, yellow-brown, finely granular, concentrically banded or zoned. The edge was comparatively thin.

Ps. longa, and *Ps. mesenterica*.—Macroscopically; like *Ps. alba*. Microscopically; round, brownish discs, somewhat zoned; internally granular becoming nucleated at the center; the periphery was thinner, coarsely granular, and zoned with granular edge. A thin bordering zone showed coiled or curled surface markings. The colonies of the two strains at first were alike, but in 4 days slow liquefaction began in those of *Ps. mesenterica*.

10. *Agar colonies*.—*Ps. alba*. Growth rapid. Colonies were at first round to irregular, smooth, edge thin and entire.

Microscopically; edge thin, undulate, finely granular (motile organism); grumose towards center. Deep colonies yellow-brown and grumose or coarsely granular. Later, macroscopically, the colonies were undulate spreading; microscopically, brown and grumose, the edge ragged, consisting of chains of organisms extending into the medium. Spreading colonies were numerous. (See Plates XV and XVI).

Ps. fluorescens.—Colonies at first punctiform becoming round, irregular and ameboid, characteristically surrounded by a hazy, ill defined, outer zone. Spiny, filamentous processes often fringed the colonies. The internal structure was at first finely granular, becoming coarsely granular to grumose at the center with a finely granular outer zone. Curled, interwoven filaments were frequently seen in the interior. Medium strongly fluorescent.

Ps. longa.—Macroscopically; punctiform, round, becoming irregular or ameboid, spreading, raised and smooth; edge at first entire, later more or less undulate. Microscopically; thin and finely granular, the edge entire to undulate. The internal structure varied from finely to coarsely granular to grumose, floccose or curled.

Ps. mesenterica.—The colonies of this strain could not be distinguished from those of *Ps. longa* except that they were frequently thinner and more widely spreading.

Ps. tenuis.—Punctiform becoming round or irregular. Microscopically; finely to coarsely granular with edge entire to broken and irregular, brownish and usually surrounded by a thin transparent granular zone.

Ps. putrida.—Punctiform to round and irregular, edge entire to broken. Colonies raised, convex, smooth to slightly convoluted. Microscopically; thin, finely granular to grumose, and showing concentric zones with radiate to irregular surface markings; the edge often becoming slightly undulate.

Strain CXII.—Colonies were round to ameboid and frequently thin and spreading. Surface smooth, sometimes concentrically ringed; usually raised, frequently becoming effuse to

hyaline. The edge varied from entire to undulate, frequently thin and spreading. Internal structure, finely to coarsely granular to grumose, often filamentous or floccose; commonly nucleated. Medium strongly fluorescent.

Strain CXV.—Punctiform to round and irregular, typically becoming ameboid spreading, frequently nucleated, somewhat raised to convex, becoming effuse or hyalin. The edge was entire to undulate or broken. Buried colonies irregular with spiny processes. Medium not fluorescent.

Strain CXL.—Round to irregular, raised, smooth, entire to broadly undulate, sometimes broken. Microscopically; finely to coarsely granular, grumose towards the center and commonly showing irregular lines, being more or less floccose or curled.

Strain CXLV.—Round, raised to convex, smooth with the edge entire to curled. Microscopically; finely to coarsely granular, becoming grumose; frequently floccose or curled.

Strain CXLVIII.—Macroscopically; round, smooth, raised, with edge thin, entire to undulate. Microscopically; finely to coarsely granular or grumose, filamentous and curled to floccose. Medium strongly fluorescent.

Strain XXXVI.—Macroscopically; round, smooth, raised, entire to thin and undulate, frequently becoming effuse. Microscopically; finely to coarsely granular, grumose, filamentous and curled to floccose; sometimes the interwoven chains of cells suggested an anthrax colony. Colonies were often surrounded by a thin transparent zone with an undulate edge.

Strain LI.—Macroscopically; round, irregular to ameboid, smooth, raised with edge entire to undulate. Microscopically; nucleated, finely to coarsely granular, becoming grumose towards the center.

II. *Cohn's nutrient solution* (27:197).—This medium was prepared as follows:

Distilled water	1000.	cc.
Di-potassium phosphate	5.	gr.
Magnesium sulphate	5.	"
Neutral ammonium tartrate	10.	"
Potassium chlorid	0.5	"

It was heated to dissolve the salts, filtered and autoclaved. Growth upon this medium occurred only with *Ps. alba*, *Ps. longa*, and strain LI (also strain LIV identical with strain LI, c. f. page 550). After 20 days, transfers of those failing to develop were made to broth and good typical growth resulted. The development of the three strains upon this medium was accompanied by more or less blue-green to yellow-green fluorescence. Multiple twinned crystals of magnesium ammonium phosphate formed at the surface, which upon attaining sufficient size (about 1 cm. in length), sank to the bottom where they were imbedded in a viscid sediment.

The medium was varied by substituting mono-potassium phosphate for di-potassium phosphate without significant effect upon the development. The character of the growth was the same upon half strength Cohn's solution.

Cultures developed a moderate clouding with white flaky particles in suspension and a white, membranous pellicle bearing crystals on the surface. More or less blue-green fluorescence appeared in the upper portions of the medium. Strain LI (LIV) and *Ps. longa* developed somewhat more slowly than *Ps. alba* and often showed a scum rather than a membranous pellicle.

Typically twinned crystals were constantly associated with development. Similar crystals were artificially formed by exposing sterile tubes of Cohn's solution in a sealed jar with very dilute ammonia. Liter flasks of Cohn's solution were inoculated with strains LI and LIV and a sufficient quantity of the crystals obtained for chemical analysis. The results showed that they were magnesium ammonium phosphate due to the ammonia produced by the bacteria.

12. *Uschinsky solution* (27:197).—The media were prepared as follows:

Distilled water	1000.	cc.
Glycerin (Merck's Blue Label)	40.	gr.
Sodium chlorid	7.	"
Calcium chlorid	1.	"
Magnesium sulphate	0.4	"
Di-potassium phosphate	2.4	"
Ammonium lactate	7.	"
Sodium asparaginate	4.	"

This was filtered and divided into two portions, one of which was used full strength and the other diluted with an equal volume of water. They were autoclaved, and inoculated at the same time from the same stock cultures.

The results attained are summarized in the following table :

TABLE 63. USCHINSKY SOLUTION

Strain	Normal solution				Diluted solution			
	Growth	Time	Fluo- rescence	Time	Growth	Time	Fluo- rescence	Time
<i>Ps. alba</i> ,	+	2 d.	+	2 d.	+	1 d.	+	1 d.
<i>Ps. fluorescens</i> ,	+	2 d.	+	2 d.	+	2 d.	+	2 d.
<i>Ps. longa</i> ,	+	2 d.	±	2 d.	+	1 d.	—	10 d.
<i>Ps. mesenterica</i> ,	+	2 d.	+	2 d.	+	1 d.	+	1 d.
<i>Ps. tenuis</i> ,	+	2 d.	±	2 d.	+	2 d.	+	2 d.
<i>Ps. putrida</i> ,	—	10 d.	—	—	—	10 d.	—	—
CXII,	+	2 d.	+	2 d.	+	1 d.	+	1 d.
CXV,	—	10 d.	—	—	—	10 d.	—	—
CXL,	+	2 d.	—	10 d.	+	1 d.	+	1 d.
CXLV,	+	2 d.	+	2 d.	+	1 d.	+	1 d.
CXLVIII,	+	2 d.	+	2 d.	+	1 d.	+	1 d.
XXXVI,	+	2 d.	—	—	+	1 d.	+	1 d.
LI,	+	10 d.	+	10 d.	+	1 d.	+	2 d.

Modified Uschinsky solution was also prepared as follows :

Distilled water	1000.	cc.
Glycerin (Merck's Blue Label).....	30.	gr.
Sodium chlorid	6.	"
Calcium chlorid	0.1	"
Magnesium sulphate (tested purity)	0.4	"
Di-potassium phosphate	2.	"
Ammonium lactate	6.	"
Sodium asparaginate	4.	"

This was filtered and divided into two portions, one of which was used full strength, while the other was diluted with an equal volume of water. Yet another solution was prepared leaving out the ammonium lactate. This was likewise divided into two portions, one being used at full concentration, the other at half concentration. The four media were inoculated at the same time from the same cultures.

The results are tabulated as follows:

TABLE 64. MODIFIED USCHINSKY SOLUTION

Strain	Uschinsky			Half strength Uschinsky		
	Growth	Time	Fluorescence	Growth	Time	Fluorescence
<i>Ps. alba</i> ,	+	20 hrs.	+	+	20 hrs.	+
<i>Ps. fluorescens</i> ,	+	2 d.	+	+	20 hrs.	+
<i>Ps. longa</i> ,	+	20 hrs.	+	+	20 hrs.	—
<i>Ps. mesenterica</i> ,	+	2 d.	+	+	20 hrs.	+
<i>Ps. tenuis</i> ,	+	20 hrs.	+	+	20 hrs.	+
<i>Ps. putrida</i> ,	—	16 d.	—	—	14 d.	—
CXII,	+	20 hrs.	+	+	20 hrs.	+
CXV,	—	16 d.	—	—	14 d.	—
CXL,	+	20 hrs.	+	+	20 hrs.	+
CXLV,	+	20 hrs.	+	+	20 hrs.	+
CXLVIII,	+	20 hrs.	+	+	20 hrs.	+
XXXVI,	+	2 d.	+	+	20 hrs.	—
LI,	+	2 d.	+	+	20 hrs.	+

Uschinsky, no lactate			Half strength, no lactate		
	Growth	Time		Growth	Time
<i>Ps. alba</i> ,	+	20 hrs.	+	+	20 hrs.
<i>Ps. fluorescens</i> ,	+	20 hrs.	+	+	20 hrs.
<i>Ps. longa</i> ,	+	20 hrs.	—	+	20 hrs.
<i>Ps. mesenterica</i> ,	+	20 hrs.	+	+	20 hrs.
<i>Ps. tenuis</i> ,	+	20 hrs.	+	+	20 hrs.
<i>Ps. putrida</i> ,	—	14 d.	—	—	14 d.
CXII,	+	20 hrs.	+	+	20 hrs.
CXV,	—	14 d.	—	+	14 d.
CXL,	+	20 hrs.	+	+	14 d.
CXLV,	+	20 hrs.	+	+	14 d.
CXLVIII,	+	20 hrs.	+	+	14 d.
XXXVI,	+	20 hrs.	—	+	14 d.
LI,	+	20 hrs.	+	+	14 d.

¹ Trace 14 days.

The development of *Ps. fluorescens*, *Ps. mesenterica*, XXXVI, and LI was more rapid but less persistent on the diluted media than on the full concentrations. All strains except *Ps. longa*, *Ps. putrida*, and CXV developed well with surface membrane and fluorescence. *Ps. longa* grew well but without fluorescence; no growth occurred with *Ps. putrida* or CXV. Transfers from tubes of these latter strains to nutrient broth developed typically, showing that the lack of growth on the Uschinsky solutions was not due to a failure to inoculate.

13. *Nitrogen*.—A nitrogen free medium was made as follows (27:198):

Water	500. cc.
Cane sugar	2.5 gr.
Mono-potassium phosphate	1. "
Magnesium sulphate	0.5 "
Sodium chlorid	0.2 "

This was heated until dissolved, and divided into two equal portions. To one was added 2 grams of ammonium tartrate, to the other 2 grams of Bausch and Lomb's peptone.

The results upon these media are tabulated as follows:

TABLE 65. NITROGEN REQUIREMENTS

Strain	Tartrate solution		Peptone solution	
	Growth	Time	Growth	Time
<i>Ps. alba</i> ,	—		+	1 d.
<i>Ps. fluorescens</i> ,	+	1 d.	+	1 d.
<i>Ps. longa</i> ,	—		+	1 d.
<i>Ps. mesenterica</i> ,	+	1 d.	+	1 d.
<i>Ps. tenuis</i> ,	+	1 d.	+	1 d.
<i>Ps. putrida</i> , ¹	+	1 d.	+	3 d.
CXII,	+	3 d.	+	1 d.
CXV,	+	3 d.	+	1 d.
CXL,	+	3 d.	+	1 d.
CXLV,	+	1 d.	+	1 d.
CXLVIII,	+	3 d.	+	1 d.
XXXVI,	+	1 d.	+	1 d.
LI,	+	1 d.	+	1 d.

¹ *Ps. putrida* showed the best growth of any at three days, with beautiful green fluorescence.

In order further to test the nitrogen requirements, the following medium was made, considerable care being taken to make it nitrogen free.

Twice distilled water	3000. cc.
Sucrose	15. gr.
Mono-potassium phosphate (tested purity, no nitrogen)	6. "
Magnesium sulphate (tested purity, no nitrogen)	0.3 "
Sodium chlorid (tested purity).....	1.5 "

After being thoroughly mixed this solution was divided into ten equal portions. One of these was reserved for a control, to another was added 2% of peptone, while to each of the other eight portions was added respectively 0.8% of the following

chemicals: asparagin, sodium asparaginate, urea, potassium nitrate, calcium nitrate, ammonium lactate, ammonium phosphate, ammonium tartrate. The ten media were inoculated at the same time from the same cultures.

TABLE 66. NITROGEN REQUIREMENTS

Strain	Asparagin		Sodium asparaginate		Urea		Peptone		Potassium nitrate	
	G.	F.	G.	F.	G.	F.	G.	F.	G.	F.
<i>Ps. alba</i> ,	+	+	+	—	—	—	+	—	—	—
<i>Ps. fluorescens</i> ,	+	+	+	+	—	—	+	+	—	—
<i>Ps. longa</i> ,	+	+	+	—	—	—	+	—	—	—
<i>Ps. mesenterica</i> ,	+	+	+	—	+	—	+	+	—	—
<i>Ps. tenuis</i>	+	+	+	—	—	—	+	—	—	—
<i>Ps. putrida</i> ,	—	—	—	—	—	—	+	—	—	—
CXII,	+	+	+	+	—	—	+	+	+	+
CXV,	—	—	—	—	—	—	+	—	—	—
CXL,	+	+	+	—	—	—	+	+	—	—
CXLV,	+	+	+	—	—	—	+	+	—	—
CXLVIII,	+	+	+	—	—	—	+	+	—	—
XXXVI,	+	—	+	—	—	—	+	+	—	—
LI,	+	+	+	—	—	—	+	+	—	—

	Calcium nitrate		Ammonium lactate		Ammonium phosphate		Ammonium tartrate	
	G.	F.	G.	F.	G.	F.	G.	F.
<i>Ps. alba</i> ,	—	—	+	+	—	—	+	+
<i>Ps. fluorescens</i> ,	—	—	+	+	—	—	—	—
<i>Ps. longa</i> ,	—	—	+	—	—	—	+	—
<i>Ps. mesenterica</i> ,	—	—	+	+	+	+	+	—
<i>Ps. tenuis</i> ,	—	—	+	—	+	+	+	—
<i>Ps. putrida</i> ,	—	—	—	—	—	—	—	—
CXII,	—	—	+	+	—	—	—	—
CXV,	—	—	—	—	—	—	—	—
CXL,	—	—	+	+	—	—	—	—
CXLV,	—	—	+	+	—	—	—	—
CXLVIII,	—	—	+	+	—	—	—	—
XXXVI,	—	—	+	—	+	+	+	—
LI,	—	—	+	+	—	—	+	—

NOTE.—G., growth; F., fluorescence; +, observed; —, not observed.

Observations upon these media were continued for over a month. Peptone was the only source of nitrogen used by all strains. Except with strain CXV, good growth was apparent in 24 hours; the latter showed good growth in 3 days. All strains, except *Ps. putrida* and CXV, were able to utilize asparagin and

sodium asparaginate. Upon ammonium lactate the results were practically the same; however, with *Ps. longa* and LI, growth was somewhat delayed. *Ps. alba*, *Ps. longa*, *Ps. mesenterica*, *Ps. tenuis*, XXXVI, and LI, used ammonium tartrate as a source of nitrogen. Upon the ammonium phosphate medium *Ps. mesenterica*, *Ps. tenuis*, and XXXVI, developed. With potassium nitrate, strain CXII showed a delayed growth. None of the strains developed on the calcium nitrate medium. *Ps. mesenterica* was the only strain which developed upon the medium containing urea.

III. PHYSICAL AND BIOCHEMICAL FEATURES.

For the purpose of determining acid production triplicate titrations of cultures and controls were made after 1, 2, 4, 10, and 20 day incubation periods. Five cc. of the medium were pipetted into 45 cc. of distilled water in Erlenmeyer flasks, boiled two minutes and titrated hot with N/20 sodium hydroxid against phenolphthalein.

1. *Sugar free medium*.—Control titrations were made upon a sugar free medium prepared as follows: 1% of Bausch & Lomb's peptone was added to distilled water and steamed in a double cooker about 50 minutes, tubed 10 cc. per tube, and autoclaved. A small amount of acid was produced on this sugar free medium by strains *Ps. putrida*, CXII, CXV, CXLVIII. Previous to boiling the acid was masked by ammonia. The figures in the table indicate the percent of normal acid or alkali produced.

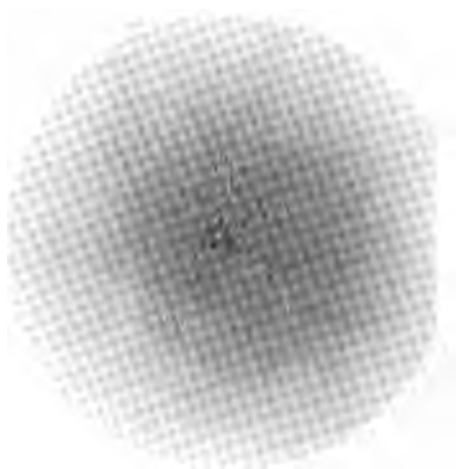
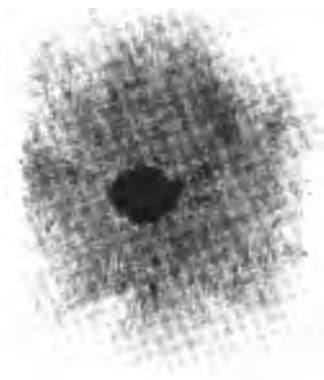


PLATE XV.—Types of agar colonies. Figure 1. *Ps. alba* (two day old colony showing anthrax-like strands). Figure 2. *Ps. fluorescens*, strain CXLVIII (two day old colony). (See pages 568-570.) $\times 40$.

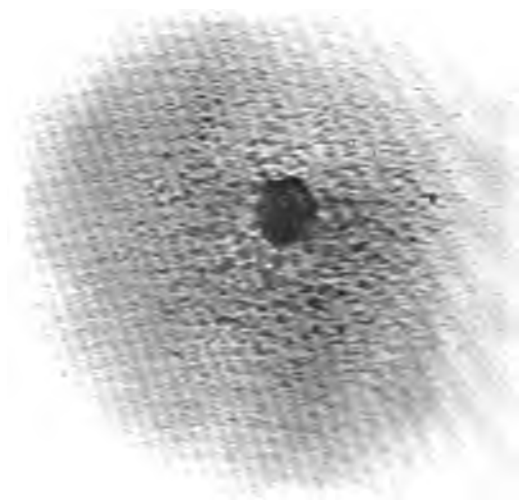
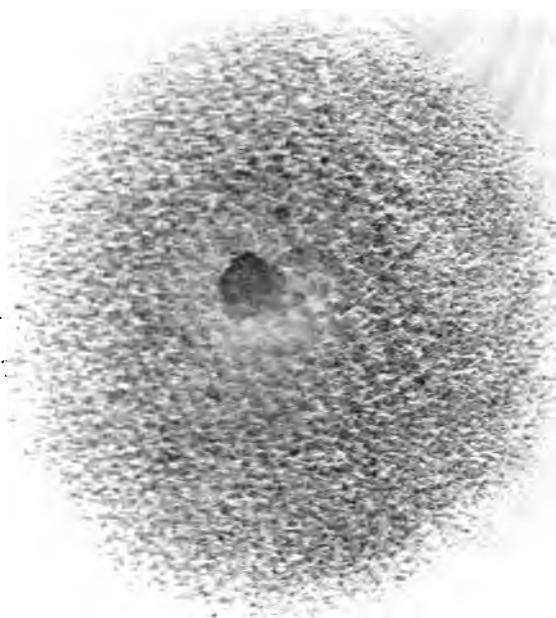


PLATE XVI.—Types of agar colonies. *Ps. fluorescens* var. *non-liquifaciens*, strain CXL; two day old colonies, showing grumose structure. (See pages 568-570.) $\times 40$.

TABLE 67. PERCENT NORMAL ACID OR ALKALI PRODUCED IN SUGAR FREE MEDIUM

Strain	1 day		2 days		4 days		10 days		20 days	
	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.
<i>Ps. alba</i> ,	0.09		0.21		0.14		0.36		0.24	
<i>Ps. fluorescens</i> ,	0.05		0.13		0.15		0.15	0.02		
<i>Ps. longa</i> ,	0.09		0.15		0.10		0.29		0.27	
<i>Ps. mesenterica</i> ,	0.16		0.14		0.20		0.31		0.28	
<i>Ps. tenuis</i> ,	0.12		0.10		0.18		0.25		0.24	
<i>Ps. putrida</i> ,	0.04		0.12		0.06	0.09		0.53		
CXII,	0.09	0.00	0.00	0.05			0.14	0.22		
CXV,	0.01		0.06		0.04	0.02		0.34		
CXL,	0.06		0.12		0.06		0.29		0.23	
CXLV,	0.05		0.10		0.18		0.34		0.19	
CXLVIII,	0.04		0.06	0.03		0.16		0.47		
XXXVI,	0.06		0.07		0.18		0.24		0.28	
LI,	0.02		0.07		0.10		0.25		0.20	

2. *Sugar media*.—To 1% peptone solutions identical with the control, 2% of dextrose, lactose, sucrose, and glycerin respectively were added. The several media were treated like the control except that they were sterilized by the intermittent method. Analytical results obtained with these four media are shown in tabular form. In general, previous to boiling, the acid produced was masked by the ammonia formed.

TABLE 68. PERCENT NORMAL ACID OR ALKALI PRODUCED ON DEXTROSE PEPTONE

Strain	1 day		2 days		4 days		10 days		20 days	
	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.
<i>Ps. alba</i> ,	0.02		0.06		0.08		0.06		0.11	
<i>Ps. fluor.</i> ,	0.03		0.15		0.14		0.08	0.09		
<i>Ps. longa</i> ,		0.02		0.03	0.03		0.03		0.04	
<i>Ps. mes.</i> ,	0.12		0.14		0.26		0.29		0.36	
<i>Ps. tenuis</i> ,	0.12		0.12		0.14		0.31		0.67	
<i>Ps. putrida</i> ,	0.00	0.00		0.03	0.00	0.00	0.03	0.00	0.00	0.00
CXII,	0.21		0.30		0.35		0.38		0.49	
CXV,	0.00	0.00		0.09	0.00	0.00	0.02		0.00	0.00
CXL,	0.00	0.00	0.01		0.13		0.25		0.28	
CXLV,	0.05		0.08		0.24		0.07		0.16	
CXLVIII,	0.05		0.16		0.30		0.44		0.52	
XXXVI,	0.11		0.07		0.10		0.00	0.00	0.00	0.00
LI,		0.02		0.02	0.05		0.00	0.00	0.00	0.00

PERCENT NORMAL ACID OR ALKALI PRODUCED ON LACTOSE PEPTONE

Strain	1 day		2 days		3 days		10 days		20 days	
	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.
<i>Ps. alba</i> ,		0.10		0.21		0.23		0.23		0.15
<i>Ps. fluor.</i> ,		0.16		0.24		0.20		0.04	0.19	
<i>Ps. longa</i> ,	0.00	0.00		0.05		0.14		0.20		0.17
<i>Ps. mes.</i> ,		0.10		0.13		0.16		0.21		0.22
<i>Ps. tenuis</i> ,		0.06		0.14		0.13		0.15		0.15
<i>Ps. putrida</i> ,		0.07		0.04		0.08	0.03		0.46	
CXII,		0.08		0.06	0.11		0.25		0.41	
CXV,		0.02		0.05		0.06	0.05		0.36	
CXL,		0.08		0.16		0.12		0.12	0.09	
CXLV,		0.11		0.15		0.15		0.21		0.15
CXLVIII,	0.02			0.02	0.15		0.41		0.93	
XXXVI,		0.10		0.13		0.09		0.09	0.04	
LI,	0.00	0.00		0.07		0.11		0.11	0.01	

PERCENT NORMAL ACID OR ALKALI PRODUCED ON SUCROSE PEPTONE

Strain	1 day		2 days		4 days		10 days		20 days	
	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.
<i>Ps. alba</i> ,	0.03			0.19		0.12		0.15		0.25
<i>Ps. fluor.</i> ,		0.05		0.05		0.16	0.09		0.08	
<i>Ps. longa</i> ,	0.02		0.00	0.00		0.09		0.10		0.17
<i>Ps. mes.</i> ,		0.03		0.08		0.12		0.14		0.17
<i>Ps. tenuis</i> ,	0.00	0.00	0.05			0.09		0.07		0.15
<i>Ps. putrida</i> ,	0.02		0.00	0.00		0.11	0.35			0.11
CXII,	0.06		0.20		0.24		0.65		0.56	
CXV,	0.06		0.05		0.00	0.00	0.08		0.10	
CXL,	0.01		0.03			0.09		0.11		0.17
CXLV,	0.00	0.00		0.03		0.12		0.14		0.16
CXLVIII,	0.00	0.00	0.00	0.00	0.15		0.58		0.60	
XXXVI,	0.03			0.01		0.15	0.02			0.01
LI,	0.04			0.06		0.14		0.09		0.14

PERCENT NORMAL ACID OR ALKALI PRODUCED ON GLYCERIN PEPTONE

Strain	1 day		2 days		4 days		10 days		20 days	
	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.	Acid	Alk.
<i>Ps. alba</i> ,		0.12		0.19		0.21		0.24		0.19
<i>Ps. fluorescens</i> ,		0.07		0.13		0.06	0.08		0.36	
<i>Ps. longa</i> ,		0.05		0.13		0.14		0.28		0.22
<i>Ps. mesenterica</i> ,		0.07		0.15		0.17		0.24		0.05
<i>Ps. tenuis</i> ,		0.01		0.12		0.16		0.13		0.11
<i>Ps. putrida</i> ,		0.02	0.04			0.02	0.22		0.71	
CXII,		0.10		0.03		0.02	0.12		0.26	
CXV,	0.00	0.00	0.03		0.03		0.07		0.20	
CXL,		0.04		0.17		0.19		0.18		0.16
CXLV,		0.11		0.16		0.12		0.26		0.16
CXLVIII,		0.01		0.03	0.13		0.69		0.87	
XXXVI,		0.04		0.14		0.02	0.13		0.29	
LI,		0.05		0.14		0.08		0.22		0.14

3. *Action on nitrates in nitrate broth.*—Medium:

Water	1000.	cc.
Peptone (Witte's)	1.	gr.
Potassium nitrate, c. p.	2.	"

The cultures were tested for nitrites by the iodo-starch reaction as follows (27:63). A starch paste was made by boiling a 4% aqueous mixture of potato starch; to the 10 cc. of culture 1 cc. of the starch paste and 1 cc. of freshly prepared potassium iodid water (0.4%) were added, followed by three drops of sulphuric acid (2 parts c. p. sulphuric acid to 1 part water). One series of cultures and controls was tested upon the second, fifth, and ninth days.

A diphenylamine reagent was prepared as follows (32:340): 5 grams of diphenylamine were dissolved in 100 cc. of pure concentrated sulphuric acid and added to 20 cc. of water. In case of negative nitrite tests with the iodo-starch reaction, a few drops of diphenylamine reagent were poured down the side of the tube in such a manner as to form 2 layers. A blue contact zone indicated the presence of nitrates. When a positive nitrite reaction was observed the nitrate test was performed with another culture.

Second day.—A positive nitrite reaction (immediate blackening) was given by *Ps. mesenterica*, XXXVI, and LI. Nitrates were present in all by the diphenylamine reaction. Ammonia was indicated in all except CXV by Nessler's reagent.

Fifth day.—An immediate reaction for nitrites was given by *Ps. mesenterica*, XXXVI, and LI. Nitrates and ammonia were indicated in all.

Ninth day.—Immediate positive reaction for nitrites occurred in cultures of *Ps. mesenterica*. XXXVI, and LI and *Ps. fluorescens* showed traces. Nitrates were indicated in all. A positive reaction for ammonia was obtained from all cultures, especially strong in *Ps. putrida* and CXLVIII.

A nitrate medium in which tap water was substituted for distilled water was employed in fermentation tubes. The tests were conducted as before, about 10 cc. of the medium being poured into clean test tubes, for this purpose.

Sixth day.—Immediate nitrite reaction occurred in the following: *Ps. mesenterica*, XXXVI, LI and a trace in *Ps. fluorescens*, while nitrates were found in all. No gas was observed. A test for nitrites was also made by the naphthlamine-sulphanilic acid reagent. A positive reaction was obtained with *Ps. mesenterica*, XXXVI, LI, and *Ps. fluorescens*. In the latter the color was not as deep as in the others.

Eleventh day.—Only slight clouding in the open arm was observed; no gas was produced. A positive nitrite reaction was obtained with *Ps. fluorescens*, *Ps. mesenterica*, XXXVI, and LI. Nitrates and ammonia were present in all by the diphenylamine and Nessler's reagents respectively. A strong reaction with Nessler's reagent was given by *Ps. putrida*, *Ps. fluorescens*, CXII, and CXLVIII.

4. *Indol.*—The tests for indol on nutrient broth and on Dunham's peptone solution were made by adding 10 drops of chemically pure sulphuric acid and 1 cc. of .02% sodium nitrite to 10 cc. of culture. The tubes were allowed to stand 10 minutes and then heated. Strains *Ps. alba* and CXL gave a trace of a reaction in 10 minutes without heating. The results on nutrient broth are given in table 69 and those on Dunham's peptone solution in table 70. A positive result is indicated by +, a negative by —, and a trace by ±.

TABLE 69. INDOL PRODUCTION IN NUTRIENT BROTH.

Strain	10 d.	13 d.	18 d.	20 d.	22 d.	24 d.	26 d.	30 d.	30 d.	30 d.	37 d.	40 d.	40 d.	40 d.	60 d.
<i>Ps. alba</i> ,	—	+	+	+	+	+	—	+	±	+	—	±	±	+	+
<i>Ps. fluor.</i> ,	—	—	—	—	—	—	—	—	—	—	—	±	±	—	—
<i>Ps. longa</i> ,	—	—	—	±	—	—	±	±	±	±	—	—	—	—	+
<i>Ps. mes.</i> ,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	±
<i>Ps. tenuis</i> ,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	±
<i>Ps. putrida</i> ,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CXII,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	±
CXV,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CXL,	+	+	+	+	+	+	+	+	+	+	±	+	+	+	+
CXLV,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	±
CXLVIII,	—	—	—	—	—	—	—	—	±	—	—	—	—	—	—
XXXVI,	—	—	—	—	—	—	—	—	±	—	—	±	—	—	—
LI,	—	—	—	—	—	±	±	±	±	±	—	±	—	—	—

TABLE 70. INDOL PRODUCTION IN DUNHAM'S PEPTONE

Strain.	2 days	6 days	11 days	26 days
<i>Ps. alba</i> ,	—	—	±	+
<i>Ps. fluorescens</i> ,	—	—	—	±
<i>Ps. longa</i> ,	—	—	—	±
<i>Ps. mesenterica</i> ,	—	—	—	—
<i>Ps. tenuis</i> ,	—	—	—	—
<i>Ps. putrida</i> ,	—	—	—	—
CXII,	—	—	—	—
CXV,	—	—	±	±
CXL,	—	—	+	+
CXLV,	—	—	—	—
CXLVIII,	—	—	—	+
XXXVI,	—	—	—	—
LI,	—	—	—	—

5. *Toleration of acids and alkalies*.—Three liters of nutrient broth were prepared in the usual way and divided into 13 portions. These separate lots were adjusted, by titrating hot against phenolphthalein with N/20 sodium hydroxid and N/20 hydrochloric acid, to the following reactions: —37.5; —30.0; —23.8; —13.5; —11.0; —7.3; 0.0; +8.8; +14.6; +25.0; +34.0 Fuller's scale.

Since alkaline media rapidly change in reaction owing to carbon dioxid absorption, control tubes of the several media were subjected to the same conditions as the cultures and their reactions determined after 1 and 3 days. Table 71 indicates the results secured upon these alkali and acid media after 24 hours' incubation. The original reactions of the several media and, also, the reactions after 24 hours are given at the top of the table. Table 72 indicates the reactions of the media and the growth of the organisms after a 3 days' incubation.

TABLE 71. GROWTH ON ACID AND ALKALI MEDIA AFTER 24 HOURS

Strain	Reaction of media previous to tubing (Fuller's Scale)					
	0.0	-7.3	-11.0	-13.5	-23.8	-37.0
	Reaction after 24 hours. (Fuller's scale)					
	+0.13	-2.0	-4.9	-7.4	-14.2	-17.9
<i>Ps. alba</i> ,	+	+	—	—	—	—
<i>Ps. fluorescens</i> ,	+	—	—	—	—	—
<i>Ps. longa</i> ,	+	—	—	—	—	—
<i>Ps. mesenterica</i> ,	+	—	—	—	—	—
<i>Ps. tenuis</i> ,	±	+	—	—	—	—
<i>Ps. putrida</i> ,	+	+	+	—	—	—
CXII,	+	+	—	—	—	—
CXV,	—	—	—	—	—	—
CXL,	+	+	—	—	—	—
CXLV,	+	+	—	—	—	—
CXLVIII,	—	—	—	—	—	—
XXXVI,	+	±	—	—	—	—
LI,	—	—	—	—	—	—

Strain	Reaction of media previous to tubing (Fuller's Scale)				
	-37.5	+8.8	+14.6	+25.0	+34.0
	Reaction after 24 hours. (Fuller's scale)				
	-22.1	+8.7	+12.5	+22.0	+33.7
<i>Ps. alba</i> ,	—	+	+	±	—
<i>Ps. fluorescens</i> ,	—	+	+	—	—
<i>Ps. longa</i> ,	—	+	+	—	—
<i>Ps. mesenterica</i> ,	—	+	+	—	—
<i>Ps. tenuis</i> ,	—	+	+	—	—
<i>Ps. putrida</i> ,	—	+	+	—	—
CXII,	—	+	+	—	—
CXV,	—	—	—	—	—
CXL,	—	+	+	—	—
CXLV,	—	+	+	—	—
CXLVIII,	—	+	+	—	—
XXXVI,	—	+	+	—	—
LI,	—	+	+	—	—

+, growth; —, no growth; ±, doubtful growth.

TABLE 72. GROWTH ON ACID AND ALKALI MEDIA AFTER 3 DAYS

Strain	Reaction after 3 days. (Fuller's scale)					
	+3.0	+0.4	-2.2	-3.3	-10.0	-14.6
<i>Ps. alba</i> ,	+	+	—	—	—	—
<i>Ps. fluorescens</i> ,	+	+	+	—	—	—
<i>Ps. longa</i> ,	+	+	—	—	—	—
<i>Ps. mesenterica</i> ,	+	+	—	—	—	—
<i>Ps. tenuis</i> ,	+	+	—	—	—	—
<i>Ps. putrida</i> ,	+	+	+	+	—	—
CXII,	+	+	±	—	—	—
CXV,	—	—	—	—	—	—
CXL,	+	+	—	—	—	—
CXLV,	+	+	—	—	—	—
CXLVIII,	+	—	—	—	—	—
XXXVI,	+	+	—	—	—	—
LI,	+	—	—	—	—	—

Strain	Reaction after 3 days. (Fuller's scale)				
	-20.0	+10.9	+13.5	+24.1	+34.6
<i>Ps. alba</i> ,	—	+	+	+	—
<i>Ps. fluorescens</i> ,	—	+	+	+	—
<i>Ps. longa</i> ,	—	+	+	—	—
<i>Ps. mesenterica</i> ,	—	+	+	+	—
<i>Ps. tenuis</i> ,	—	+	+	—	—
<i>Ps. putrida</i> ,	—	+	+	—	—
CXII,	—	+	+	+	—
CXV,	—	—	+	—	—
CXL,	—	+	+	—	—
CXLV,	—	+	+	+	—
CXLVIII,	—	+	+	+	—
XXXVI,	—	+	+	+	—
LI,	—	+	+	—	—

+, growth; —, no growth; ±, doubtful growth.

6. *Optimum reaction for growth in bouillon.*—In connection with the experiments on the toleration of sodium hydroxid and hydrochloric acid, observations were made after a day's incubation as to the optimum reaction for growth. The best growth with all strains was found to occur in a very slightly acid medium. The figures given in table 73 represent the original reaction of the media in which growth occurred in 24 hours (c. f. page 582 for actual reactions). The reactions at which the best growth occurred are shown in black face.

TABLE 73. OPTIMUM REACTION

Strain				Reactions		
<i>Ps. alba</i> ,				0.0	+8.8	+14.6
<i>Ps. fluorescens</i> ,		-7.3		0.0	+8.8	+14.6
<i>Ps. longa</i> ,				0.0	+8.8	+14.6
<i>Ps. mesenterica</i> ,				0.0	+8.8	+14.6
<i>Ps. tenuis</i> ,				0.0	+8.8	+14.6
<i>Ps. putrida</i> ,	-11.0	-7.3		0.0	+8.8	+14.6
CXII,				0.0	+8.8	+14.6
CXV, ¹						
CXL,				0.0	+8.8	
CXLV,		-7.3 ²		0.0	+8.8	+14.6
CXLVIII,				0.0	+8.8	+14.6
XXXVI,				0.0	+8.8	+14.6
LI,				0.0	+8.8	+14.6

¹ No growth at 24 hours.² Trace of growth.

7. *Vitality on culture media*.—Long vitality on culture media was characteristic. Five month agar cultures completely dried down, developed promptly with fluorescence when transferred to nutrient broth.

8. *Temperature relations; thermal death point*.—Thin walled tubes of uniform thickness with an inside diameter of 15 to 17 mm. were chosen for the determinations of the thermal death point. Seven cc. of bouillon, +10 Fuller's scale, were employed in each case. The inoculations were made from young broth cultures, care being taken not to wet the tube above the surface of the medium. In the preliminary determinations the tubes were deeply submerged in the thermal bath for 10 minutes at the following temperatures: 44.5, 47.7, 54.5, 58.4, 61.3° C. After exposure the tubes were incubated at 25° C. In this way the thermal death point for all strains was roughly fixed between 47.7 and 54.4° C. None grew after exposure at 54.5° C.

In subsequent trials the temperature of the bath was varied so as to determine the death point more closely. A very large

number of tests were made in an effort to fix the exact death point accurately, but the experiments indicate clearly that the death point of these organisms under the conditions employed, is not constant within at least 0.5° C. The final conclusions are recorded in the table below:

TABLE 74. THERMAL DEATH POINT

Strain		°C.	°C.
<i>Ps. alba</i> ,	between	53.5	and 53.9
<i>Ps. fluorescens</i> ,	"	53.1	" 53.5
<i>Ps. putrida</i> ,	"	53.5	" 53.9
<i>Ps. longa</i> ,	"	51.1	" 51.5
CXL,	"	51.5	" 51.8
CXLVIII,	"	51.5	" 52.9
CXLV,	"	50.2	" 50.5
CXII,	"	50.2	" 51.5
CXV,	"	50.2	" 50.5
XXXVI,	"	50.2	" 50.5
<i>Ps. mesenterica</i> ,	"	49.3	" 50.2
LI,	"	49.1	" 49.3
<i>Ps. tenuis</i> ,	"	48.3	" 49.1

Optimum temperature.—The best growth with all strains occurred at approximately 25° C.

Maximum temperature.—At 36.7 to 35° C. only *Ps. fluorescens* and *Ps. putrida* developed in 24 hours. At 33.4 to 30.8° in the same length of time *Ps. alba*, *Ps. fluorescens*, *Ps. longa*, *Ps. mesenterica*, *Ps. putrida*, CXII, and CXL, showed growth. At 31.2 to 28.5° *Ps. alba*, *Ps. fluorescens*, *Ps. longa*, *Ps. mesenterica*, *Ps. tenuis*, *Ps. putrida*, CXII, CXL, and LI developed. The experiments indicated that all strains could grow at temperatures up to 33° C. Only *Ps. fluorescens*, *Ps. putrida*, and CXV developed at 36° C. in 7 days. In no case was the growth at these higher temperatures as good as it was below 30° C.

9. *Drying.*—Small cover slips were placed on bits of paper in petri dishes and sterilized in the oven. Each was then inoculated with one loop of young broth culture, the age of which varied in the different experiments from 1 to 3 days. They were allowed to remain in the dark at room temperature. At intervals, cover slips were removed and dropped into tubes of

sterile broth. A characteristic growth after incubation was regarded as evidence of continued vitality. It is to be noted that in general the organisms retained their vitality longer when taken from the older cultures than when taken from day old cultures.

TABLE 75. RESISTANCE TO DESICCATION

Strain	Days dried							
	1	2	2	2	3	3	4	4
<i>Ps. alba</i> ,			+	—	+	+	—	+
<i>Ps. fluorescens</i> ,	+		+	+			+	+
<i>Ps. longa</i> ,	+		+	—			—	
<i>Ps. mesenterica</i> ,	+			+			—	
<i>Ps. tenuis</i> ,	—			—				
<i>Ps. putrida</i> ,	+		+	+	+	+	+	+
CXII,	+	—	+	+	+	+	+	+
CXV,		—		—	+	+	—	
CXL,	+	+	+	—			—	
CXLV,	+	+	+	+			+	+
CXLVIII,	+		+	+	+	+	+	+
XXXVI,	+	+	+	+	+	+	+	+
LI,	+	+		+			—	

Strain	Days dried							
	6	6	6	10	14	18	20	30
<i>Ps. alba</i> ,						—		—
<i>Ps. fluorescens</i> ,						—		—
<i>Ps. longa</i> ,						—		—
<i>Ps. mesenterica</i> ,						—		—
<i>Ps. tenuis</i> ,						—		
<i>Ps. putrida</i> ,		+	+	+		+		+
CXII,	+	+	+	+	—	+	—	—
CXV,	—				—	—	—	—
CXL,	+				—	—	—	—
CXLV,	—				—	+	—	—
CXLVIII,		+	+	+		+		+
XXXVI,	—	+	+		—	+	—	—
LI,	+				+	—	—	—

+, growth; —, no growth; ±, doubtful growth.

10. *Insolation*.—Agar plates, one-half covered were exposed on snow to bright sunlight for 10 minutes at 11 a. m. Feb. 29. All were sensitive, the percent killed varying from 23 to 100%. The number of colonies on the unexposed half,

the number on the exposed half, and the percent killed are indicated below :

TABLE 76. INFLUENCE OF INSOLATION

Strain	Number of colonies on unexposed half	Number of colonies on exposed half	Percent killed
<i>Ps. alba</i> ,	225	70	69
<i>Ps. fluorescens</i> ,	340	100	70
<i>Ps. longa</i> ,	68	21	60
<i>Ps. mesenterica</i> ¹	24	2	92
<i>Ps. tenuis</i> ,	280	18	93
<i>Ps. putrida</i> ,	numerous	0	100
CXII,	18	0	100
CXV,	280	56	80
CXL,	numerous	0	100
CXLV,	186	142	23
CXLVIII, ¹	8	2	75
XXXVI, ¹	countless	42	95
LI,	numerous	0	100

¹ Percent could only be estimated on account of spreaders.

Ten minutes exposure of strains CXII, CXV, CXL, CXLV, CXLVIII, XXXVI, and LI, March 8, at 11 a. m. gave results indicated in table 77.

TABLE 77. INFLUENCE OF INSOLATION

Strain	Plate No.	Number of colonies on unexposed half	Number of colonies on exposed half	Percent killed
CXII,	1	350	0	100
	2	413	0	100
CXV,	1	38	0	100
	2	6	0	100
CXL,	1	1494	0	100
	2	2289	0	100
CXLV,	1	381	0	100
	2	540	0	100
CXLVIII,	1	318	127	60
	2			
5,	1	540	226	58
	2	763	85	89
XXXIII,	1	countless	0	100
	2	"	0	100
XXXVI,	1	381	0	100
	2			
LI,	1	158	0	100
	2	222	1	99.5

11. *Acids produced*.—Hydrogen sulphid. Tubes of nutrient broth were prepared and inoculated in the ordinary way and in each, including controls, was suspended a strip of filter paper thoroughly moistened with lead acetate solution. Blackening of the paper after a suitable incubation of the cultures indicated the presence of hydrogen sulphid. The following strains gave this reaction constantly, CXV, CXL, *Ps. tenuis*. With strain CXV it was in evidence in 2 days; with *Ps. tenuis* and CXL, in 5 to 6 days. A slight reaction was observed in tubes of LI and a doubtful trace occasionally in *Ps. putrida*, CXII, and CXLV.

12. *Alkalies produced*.—Ammonia was indicated by Nessler's reagent in nitrate broth cultures of all strains (c. f. page 579).

13. *Crystals*.—Crystals of magnesium ammonium phosphate were formed in Cohn's solution by *Ps. alba*, *Ps. longa* and strain LI.

14. *Diastasic action on potato starch*.—Broth cultures of the 13 strains were tested for diastasic action upon potato starch after incubation periods of varying duration. The results were negative.

15. *Anaerobiosis*.—Pyrogallic acid oxygen absorption method: Freshly prepared agar slants were placed in a liter Novy jar containing 15 grams of pyrogallic acid. Just before sealing about 200 cc. of a 1% sodium hydroxid solution was added. After 10 days incubation in the sealed jars a slight growth with fluorescence was apparent in strains *Ps. alba*, *Ps. fluorescens*, *Ps. longa*, *Ps. mesenterica*, *Ps. tenuis*, CXII, CXL, CXLV, CXLVIII, XXXVI, and LI. No growth resulted with *Ps. putrida*, or CXV; however, normal growth occurred in tubes of the latter two strains soon after they were removed from the jar.

Carbon dioxid method.—Carbon dioxid was produced from washed and boiled marble and hydrochloric acid in a Kipp generator and purified by passing successively through solutions of

sodium carbonate, potassium permanganate, pyrogallic acid in 1% sodium hydroxid, and distilled water and allowed to pass for 2 hours through a Novy jar containing freshly prepared agar slants. The jar was sealed and held at room temperature. No strain showed growth after 5 days incubation, but in all cases good growth occurred in from 1 to 2 days after the seal was broken. A second series incubated for 10 days gave duplicate results. In addition to the plain agar slants, lactose and dextrose agar slants were used with similar results. The reaction of the incubated agar medium was roughly determined by triturating 5 cc. of the solid medium in 45 cc. of distilled water and titrating. Sufficient carbon dioxid had been absorbed to give the cold medium a reaction of +20 Fuller's scale.

In order to be sure that the failure to grow in the carbon dioxid was not due to the acidity of the medium, augmented by absorbed carbon dioxid, the following anaerobic methods were employed.

Hydrogen method.—A series of plain agar slants and a series of 1% dextrose litmus agar slants were placed in a Novy jar and the air displaced by hydrogen. The jar was exhausted in order to hasten the displacement. The litmus agar remained neutral, and titrations of the plain agar controls without boiling demonstrated that the reaction had not been changed. No growth occurred in 10 days. All developed well when removed from the jar.

Roux method.—Sterilized Roux tubes were aseptically filled with young broth cultures of the 13 strains. This test was tried several times and in no case did growth appear except in defective tubes or in those containing air bubbles. After incubation of 10 days the tubes were broken and the contents gathered in sterile test tubes where normal growth resulted.

These tests show that the various strains are strictly aerobic. They further indicate that lactose and dextrose are not fermented in the absence of oxygen. (Consult papers of Andrewes and Hordu (1) and Glenn (10) in bibliography).

GROUP NUMBER OF THE 13 STRAINS

The group number of the 13 strains was easily computed with the exception of the digits representing the action of the bacteria upon carbohydrates and glycerin. On account of the formation in the control, i. e., peptone solution, of decomposition products having an acid reaction, there is some doubt in certain cases whether the acid in the sugar and glycerin peptone media resulted from oxidation of the introduced compounds, or from proteid decomposition. In each case the amount of acid produced in the carbohydrate media was compared with the amount, if any, produced in the control, and where the difference was less than 0.2% the digit representing no acid production was recorded. However a comparison of the tables will show that no sharp line of differentiation exists between acid production and no acid production.

The group numbers determined were as follows:

<i>Ps. alba</i> ,	212.2332133	}	Non-liquefiers
<i>Ps. longa</i> ,	212.3332133		
<i>Ps. putrida</i> ,	212.3332132		
<i>Ps. mesenterica</i> ,	211.2333133	}	Tardy liquefiers
<i>Ps. LI</i> ,	211.2233133		
<i>Ps. tenuis</i> ,	211.2322133		
<i>Ps. CXL</i> ,	211.2222133		
<i>Ps. fluorescens</i> ,	211.2223132	}	Rapid liquefiers
<i>Ps. CXII</i> ,	211.2222133		
<i>Ps. CXLV</i> ,	211.2332133		
<i>Ps. CXLVIII</i> ,	211.2222132		
<i>Ps. XXXVI</i> ,	211.2223132		
<i>B. CXV</i> ,	211.3332733		Doubtfully fluorescent

SPECIES

As already noted bacteriological literature contains descriptions of over 50 species of bacteria which are capable of producing green fluorescence upon the common media. However, it is probable that many so-called species are identical with, or varieties of, previously named species. The following references from literature are cited as illustrations of the trend of opinion.

Niederkorn (23) concluded that there are only two constant forms, *B. fluorescens liquefaciens* Flügge and *B. pyocyaneus* Gessard, among the following:

<i>Bacillus pyocyaneus</i> ,	a	Gessard.
" "	b	Ernst.
" "	c	Freudenreich.
" "	<i>pericardit.</i>	Harold-Ernst.
" "		vom bakt. Institut. Travel.
" "		strumit. Lanz, Bern.
" <i>fluorescens</i>	<i>liquefaciens</i>	Flügge.
" "	<i>albus</i>	Adametz.
" "	<i>aureus</i>	Zimmermann.
" "	<i>longus</i>	"
" "	<i>tenuis</i>	"
" "	<i>mesentericus</i>	Tataroff.
" "	<i>putridus</i>	Flügge.
" "	<i>capsulatus</i>	Pottlien.
" "	<i>liquefaciens</i>	(vom Verf. aus Wasser isoliert).

Ruzicka (24) shows that *B. pyocyaneus* and *B. fluorescens liquefaciens* vary so widely within the species and so overlap in their cultural characters that no sharp line of differentiation between them can be drawn.

Griffon (11) states that *B. caulivorans*, *B. brassicaeovorans* and *B. aeruginosus* are not to be considered as distinct species, but only as forms of *B. fluorescens* which, under a favorable environment, easily changes from a saprophytic to a parasitic existence. He holds that *B. aeruginosus* is to be considered synonymous with *B. fluorescens putridus*.

According to various authors: *B. fluorescens non-liquefaciens* is synonymous with *B. fluorescens putridus* and representative of the group comprising *Bacillus fluorescens tenuis*, *Bacillus fluorescens aureus* and *Bacillus fluorescens crassus*; *Bacillus viscosus* Frankland is synonymous with *Bacillus fluorescens liquefaciens*, and *Bacillus fluorescens fuscus* corresponds to *Bacillus oogenes fluorescens*.

In view of the above citations it is evident that the fluorescent organisms are closely related, probably being varieties of one polymorphic species. Before stating the conclusions which have been drawn concerning the number of species represented in the seven strains of sap bacteria and the six known strains

which were studied, attention is directed to a few clauses abstracted from Flügge's description of his *Bacillus fluorescens liquefaciens* (6:II: 292). "The degree of liquefaction varied very considerably. There were varieties which in 2 days and others which first in 2 weeks liquefied the gelatin; the form of the colonies varied, also, from spherical to spreading with border entire to toothed. The optimum temperature was 20° to 25° C. Many varieties do not grow at 37° C, others grow well and form on agar a more or less thick layer. The oxygen requirements are equally variable; through them are explained the different forms of liquefaction in stab cultures. If one wishes to conceive all minor variations as constant characters, one must make dozens of varieties."

According to Flügge (l. c.) *Bact. butyri fluorescens* Laffar, *B. fluorescens nivalis* Schmelck, *Bacillus viscosus* Frankland and *B. fluorescens minutissimus* Unna may be regarded as synonymous with *B. fluorescens liquefaciens*. In the description of *B. fluorescens non-liquefaciens*, he says, "A sharp line between the *liquefaciens* and *non-liquefaciens* variety of *B. fluorescens* does not exist since there are forms which in the first day of plate growth appear to belong to the latter group, which later sink gradually in the gelatin."

It is believed that the morphological, cultural, physical and biochemical features of the 13 strains of green fluorescent bacteria warrant the assumption that there are but two species represented: *Pseudomonas fluorescens* and an unknown species, strain CXV, which, as has been previously noted (c. f. page 546), never evidenced more than doubtful fluorescence.

Ps. fluorescens is represented by 12 strains which are divisible into two varieties, *liquefaciens* and *non-liquefaciens*. The following strains belong to the *liquefaciens* variety: *fluorescens mesenterica*, CXII, CXLV, CXLVIII, XXXVI and LI. To the *non-liquefaciens* variety belong, *alba*, *longa*, *putrida* and, provisionally, *tenuis* and strain CXL, which showed a very tardy

liquefaction of gelatin but in other respects closely resembles the other three strains.

New species.—Strain CXV: This strain appears to be different from any of the others studied. A feeble trace of fluorescence was thought to have been present at times in agar cultures. Repeated staining for flagella has shown that the latter are peritrichiate. Another peculiarity about this organism is the parallel grouping of single or double cells common in capsule and flagella preparations, c. f. Plate X, figures 3 and 4. As previously noted several cells commonly occurred side by side in the same capsule with several flagella arising about the periphery of the latter. A careful consideration of the character of this bacillus seems to justify the conclusion that it is a distinct species. The name *Bacillus parallelus* is proposed for this organism. For purposes of reference the differential characters of this new species are summarized as follows:

BRIEF DESCRIPTION OF *BACILLUS PARALLELUS*
(NEW SPECIES)

I. MORPHOLOGICAL CHARACTERS

1. *Form.*—A short motile bacillus with rounded ends occurring singly, typically in twos; long chains common upon solid media.

2. *Size.*—Individual cells had the following dimensions. On hanging blocks; length 1 to 2.6 microns, diameter .8 to 1.0 microns. Hanging drops; length 1.6 to 4.0 microns, diameter .5 to .9 micron, stained preparations; length .8 to 2. microns, diameter .5 to .8 microns.

3. *Grouping.*—Short and long chains; delicate membranous pellicle.

4. *Endospores.*—None observed.

5. The flagella were peritrichiate: tufts were common at each end of short chains, but lateral flagella were also present on what appeared to be individual cells. Easily demonstrated by Löwit's or Loeffler's method.

6. *Capsules.*—Capsules easily demonstrated upon preparations from 10 day broth cultures by Welch's method or Richard Muir's contrast stain. Frequently 2 and as many as 5 cells occurred side by side within the same capsule with flagella arising about the periphery of the envelope.

7. *Zoogloea.*—Small zoogloea masses were common in liquid cultures.

8. *Staining reactions.*—Gram's stain: Deeply stained even after 15 minutes in absolute alcohol; with amyl alcohol, Gram's stain was irregularly retained after 5 minutes' exposure. Aqueous fuchsin: deeply stained. Aqueous gentian violet: well stained. Carbol fuchsin (Ziehl): well stained.

II. CULTURAL FEATURES

1. *Agar stroke.*—Not characteristic; a narrow filiform, white slimy to viscous band. Doubtful fluorescence of the medium.

2. *Potato*.—A narrow, slimy, filiform band, becoming brownish; sometimes the growth became dull and more or less rhizoid in character; the medium was more or less grayed.

3. *Agar stab*.—Best growth at top, colony at first white, becoming brownish; development somewhat restricted; the line of puncture was at first beaded to filiform, becoming somewhat villous. The medium showed a very slight fluorescence and in old cultures became amber brown.

4. *Gelatin stab*.—Growth best at the top; line of puncture filiform to beaded; liquefaction at first crateriform, later stratiform, beginning in 24 hours and proceeding rapidly at first; complete in 62 days.

5. *Nutrient broth*.—Rather slow growth; moderate uniform clouding in from 2 to 5 days; transient; white membranous coherent precipitate; old cultures were brownish and stringy.

6. *Milk*.—Digestion apparent in about 4 days; a firm coagulum appeared in about 18 days accompanied by acid production; digestion was completed in from 30 to 104 days: the medium never appeared green but was more or less straw colored throughout.

7. *Litmus milk*.—Alkaline reaction in 4 days, succeeded by slight acid production when digestion began; the litmus was completely reduced in 2 or 3 weeks' time.

8. *Gelatin colony*.—Rapid growth; first punctiform to round and entire, rapidly sinking in the saucer-like depressions of the liquefying gelatin.

9. *Agar colonies*.—Punctiform and round to irregular and ameboid; the colonies effuse or raised and convex; the edge thin entire to undulate and broken; finely to coarsely granular to grumose; commonly nucleated. Colonies dense, dark brown, fringed with spiny processes occurred less frequently.

10. *Cohn's solution*.—No growth.

11. *Uschinsky solution*.—No growth.

12. *Nitrogen requirements*.—Nitrogen obtained from peptone and ammonium tartrate.

III. PHYSICAL AND BIOCHEMICAL FEATURES

1. *Action upon carbohydrates in peptone solution.*—Neither acid nor gas were formed in 1% peptone solutions containing 2% of either dextrose, lactose, sucrose or glycerin.

2. *Ammonia production.*—Moderate ammonia production; 18.6 cc. N/10 hydrochloric acid equivalent produced in 100 cc. of broth in 10 days.

3. *Nitrates in nitrate broth.*—Not reduced. Nitrates and ammonia present; ammonia probably from proteid decomposition.

4. *Indol production.*—Doubtful in 11 day Dunham's peptone cultures after boiling; absent in nutrient broth.

5. *Toleration of acids and alkalies.*—Slight.

6. *Optimum reaction for growth.* +15 Fuller's scale.

7. *Vitality on culture media.*—Long.

8. *Temperature relations.*—Thermal death point; between 50.2 and 50.5° C. Optimum temperature approximately 25° C.; maximum, 37° C; minimum, 5-7° C.

9. *Resistance to desiccation.*—Continued vitality after 3 days drying on cover slips; 4 days fatal.

10. *Insolation.*—Sensitive; 80 to 100% killed after 10 minutes' exposure.

11. *Acids produced.*—Abundant hydrogen sulphid production.

12. *Alkalies.*—Moderate ammonia production.

13. *Relation to oxygen.*—Strict aerobe.

14. *Group number.*—Bacillus 211.3332?33.

BRIEF CHARACTERIZATION OF THE 12 STRAINS OF *Ps. fluorescens*

For the convenience of any one who may have occasion to review these results the brief characterization items of the six strains of fluorescent bacteria isolated from maple sap together with those of strains *alba*, *fluorescens*, *longa*, *mesenterica*, *tenuis*, and *putrida* are summarized in tabular form on pages 598 and 599.

CONCLUSIONS

Among the 42 strains of green fluorescent bacteria, selected from several hundred strains which had been isolated from maple sap, there were 32 strains of the *liquefaciens* and 9 strains of the *non-liquefaciens* varieties of *Ps. fluorescens*. The studies included one strain which was never more than doubtfully fluorescent which, for this and other reasons, should not properly be regarded as a member of the fluorescent group. The 9 strains of the *non-liquefaciens* variety showed a delayed liquefaction of gelatin in from 50 days to 5 months when cultivated in a moist chamber at 20° C. Peptonization of milk by these strains was also long delayed commencing in from 30 days to 3 months.

Critical comparative studies of 7 representative strains of green fluorescent sap bacteria and 6 so-called species *Ps. alba*, *Ps. fluorescens*, *Ps. longa*, *Ps. mesenterica*, *Ps. tenuis*, and *Ps. putrida* show that no sharp line of differentiation can be drawn between these forms. Of the known "species," *Ps. alba*, *Ps. longa*, and *Ps. putrida* fail to liquefy gelatin in 6 months time, while in the case of *Ps. mesenterica* and *Ps. tenuis* a delayed liquefaction occurs. In the latter named strain liquefaction first appears 4 months after inoculation.

It is believed that the fluorescent sap bacteria as well as the so called species, *Ps. alba*, *Ps. longa*, *Ps. mesenterica*, *Ps. tenuis*, and *Ps. putrida* should properly be recognized as strains of the *liquefaciens* and *non-liquefaciens* varieties of *Ps. fluorescens*.

TABLE 78. BRIEF CHARACTERIZATION

MORPHOLOGY	Diameter over 1 micron	
	Chains	
	Endospores	
	Capsules	
	Pseudozoogloea	
	Motile	
	Gram's stain	
CULTURAL FEATURES	Broth	Cloudy
		Pellicle
		Sediment
	Agar Gel. plate	Shining
		Round
	Gel Stab	Surface-growth
		Needle-growth
	Potato	Moderate
		Discolored
	Grows, at 37° C.	
BIOCHEMICAL FEATURES	Grows, in Cohn's solution	
	Grows, in Uchinsky solution	
	Lique- faction	Gelatin ¹
		Casein
		Agar
	Milk	Coagulated ²
		Casein peptonized ³
	Indol	
	Hydrogen sulphid	
	Ammonia	
	Nitrates reduced	
	Fluorescent	

¹ Under observation 6 months.² Coagulum more or less jelly-like in consistency.³ Under observation 4 months.

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